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OBJECT LESSONS FROM NATURE.

OBJECT LESSONS

FROM

NATURE :

A First Book of Science.

BY

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P R E F A C E.

THIS little book is intended as a first guide to the study of Nature. Those who have attended to the minds of children and to the way in which they develop, are agreed that the faculty of observation is strong at an early age, and that it can then be most profitably cultivated. Systems and theories belong to a later stage when the reasoning powers are in fuller activity. The best educational authorities have been led by these considerations to recommend Graded Object-lessons as a profitable exercise for young children, and the benefit of such lessons is established by the practical experience of many teachers. The objects upon which useful lessons can be founded are infinitely varied. Houses and the materials used in building, common articles of household use, and the simpler machines and tools, are preferred by some people, and would, no doubt, be admitted by all. The late Professor Guthrie's "First Book of Knowledge" shows how such objects may be treated in a class lesson. Natural History offers advantages of its own. Nowhere else than in Nature can we find objects of equal beauty, or examples equally perfect of the adaptation of means to ends. I cannot find that nearly enough use has been made of natural objects for the teaching of observation. Want of opportunity prevents most town-children from getting any real acquaintance with the world of life, but it is not impossible to increase materially the opportunities which at present exist. No doubt the very best way of opening a child's eyes and mind to the delightful contrivances of Nature is the country walk with a companion skilled in Birds and Insects and Flowers, and not impatient of childish questions. At present there are few children who can find such teaching,

and we have to look out for the best possible substitute, which seems to be bright and lively school-lessons, in which natural objects are produced and explained. I have here tried to suggest a few lessons from Nature. — an endless variety for further choice.

The lessons are meant for reading aloud, but the teacher will, I hope, use them in his own way. One thing only appears to me essential, viz. that *objects* (if not the very things named in this book, then some others) shall be actually seen and handled. Talks about Nature will be profitable only when natural objects are directly observed. Pictures may be shown side by side with natural objects, but should never usurp their place. A magic-lantern may often be used with advantage, and the woodcuts in this book, or any others, may be reproduced as photographic lantern-slides at a cheap rate. It is not necessary to darken the room if strong light is kept from falling upon the lantern-screen.

I believe that there is great value in continual questioning, and that these pages will be dull and unprofitable if merely read steadily through.

What is put down in the book for one lesson may now and then prove to be more than the class can profitably go through in the time at command. I hope that the teacher will divide such lessons, and in all things use his own judgment. There must be full liberty to add, leave out, expand, or substitute more accessible objects.

The plan of the book is shortly this. Simple explanations about animals and plants, with very familiar examples, described in some detail, come first. These early lessons are meant to give a small stock of information, to teach the habit of careful examination of all the details of any natural object, and to prompt questions. Then some chemical and physical facts are introduced, and experiment is brought in. Upon this foundation some simple lessons on Clouds, Rain, and Rivers, and on the food of Plants, are based.

If we were to call these lessons a course in Zoology,

Botany, Chemistry, and so forth, we should not only be using needlessly important words, but we should disguise the main purpose of the book, which is to explain the ~~simplest~~ simplest natural phenomena to children who are incapable of continuous and methodical thought. To the child there ought to be no separate sciences at all, and the scientific methods explained to him should be treated, not as the thin end of such formidable wedges as Chemistry and Physiology, but as ways of throwing light upon certain natural facts about which he has been led to feel some curiosity.

There is one thing which passes without mention in the lessons, which is of the first importance. It is this—that everything learnt must be a means to something done. Something must be tried as a little private experiment, or something gathered and preserved, or something drawn, or something questioned, and made to tell its tale. In my own teaching-routine drawing plays a great part; and there is no better way of checking mental indolence, and the miserable habit of trying to learn with both eye and mind out of focus. I have rather reluctantly given up the intention of setting such work in the lessons, in order to preserve the natural liberty of the teacher, who ought to judge for himself what can be profitably attempted.

My colleague, Professor Smithells, has very kindly contributed three lessons, viz. those on Air and Burning in Air, the Composition of Water, and the Candle-flame. Mr. W. Dyche, late Science Master of the Higher-Grade Board School, Leeds, and now Head-Master of the Higher-Grade Board School, Halifax, has been good enough to read through the proofs, and make suggestions founded upon his own experience in teaching science to young people.

The lessons have been written for children of about twelve years old, but bright and forward children might follow a good deal, at least, of the explanations at an earlier age, as I have found by actual trial.

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OBJECT LESSONS FROM NATURE.

LESSON I.

SOME COMMON QUADRUPEDS.

WANTED :—*Skulls of Cat and Dog. Stuffed Squirrel, Vole, Shrew, and Bat.*

Higher and Lower Animals.—I am going to talk to you to-day about animals. Some animals are very like ourselves. They have eyes, and ears, and nose, and mouth; a heart with red blood, a brain, lungs to breathe with, and some kind of voice. But there are others which have none of these things, and hardly look like animals at first sight. Some animals are very sensible, and understand if we talk to them. But many are almost like plants; they cannot move about, or see or hear, and they take no notice of what is said to them. Which is the most sensible animal you know? Probably you will answer, the Dog, and I think that is a good answer. A Snail is a much duller and less sensible animal than the Dog. If you go to the seaside, you may find small red animals called Sea-anemones on the rocks at low water. Some will be found in the water, and some out of it. They are about the size of half a crown, and quite soft, without bones or shell. They have no head or legs, no eyes, or ears, or nose, or heart, or blood, or lungs. They have a mouth, however. They hardly ever move,

and can only creep very, very slowly. If you touch them they seem to feel, for they shrink, and make themselves as small as they can. Why do we call the Sea-anemone an animal? Because it has a ~~mouth~~ ^{mouth} for feeding, and it can feel, though not very much. We

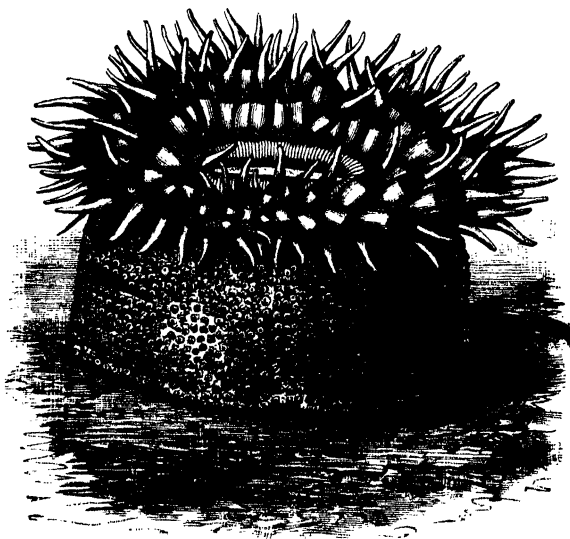


Fig. 1.—SEA ANEMONE.

call the Sea-anemone a very *low* animal, because it is so simple. The Snail is *higher* than the Sea-anemone, for it has eyes, and a lung, and a heart, and though it has no legs it can creep pretty well. I do not think you have ever seen a Snail's eyes. They are very small, and are carried on the horns which many of you must have seen. The Snail does not see things distinctly, but can tell light from darkness, like a man who keeps

his eyes shut. The Dog is far *higher* than the Snail, for he is quick to see, and smell, and hear, and can even understand words. He can run fast, much faster than a ~~man~~. He has very nearly all the organs of a man. What do we mean by *organs* of the body? Such things as the heart, stomach, lungs and brain, each of which does some special thing. The heart drives the blood through the body, the stomach digests our food; the lungs purify the blood by bringing air

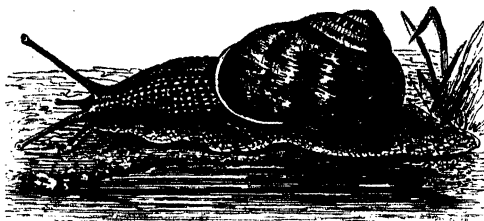


Fig. 2.—GARDEN SNAIL.

to it; by the brain we feel and think. All these are organs of the body, and the Dog, as I have told you, has nearly the same organs that we have.

Mammals.—The Dog is one of the animals which we call Quadrupeds, or Mammals. All Mammals when very young suck the milk of the mother, and they are nearly always covered with hair. The Dog, Cat, and Sheep are Mammals. Do you know any other Mammals? The Cow, Rabbit, Guinea-pig, Lion, Horse are Mammals too. There are many different sorts of Mammals. Some live on land, some in the sea. Some run, some climb, some swim, some fly. Some live by hunting, some by grazing in the fields. Some are fierce, some are gentle. They never have feathers,

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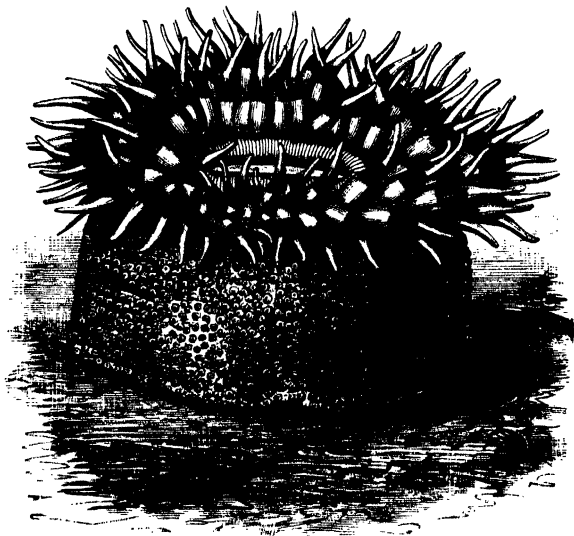


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and become sociable in consequence. Wild Cats go alone, and never hunt in packs.

Hunting and Grazing Animals.—Both Dogs and

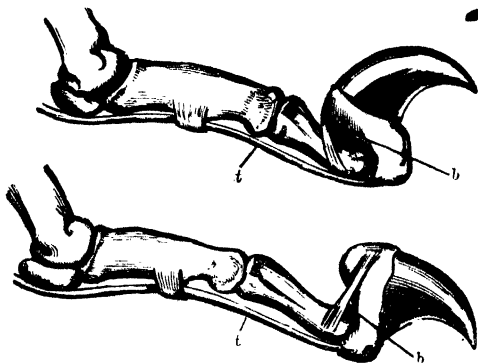


Fig. 6.—BONES OF A CAT'S TOE.

In the upper figure the claw is raised by the elastic band *b*. In the lower figure it is brought down by the pull of the long tendon *t*.

Cats are *Hunting animals*. That is why they have sharp teeth and long claws. Some animals never hunt, but feed on grass in the fields. We might call these *Grazing animals*. Their teeth are not pointed, and may be almost flat. They have no claws on their feet, but hoofs.



Fig. 7.—TEETH OF CAT, ADAPTED TO CUTTING AND TEARING FLESH.

Squirrels.—Squirrels are common in great woods, but we do not see them near

creatures. They are about as big as a kitten, and of a reddish brown colour. They have long, bushy tails,

Squirrels run from bough to bough, and from tree to tree. Now and then they leap to the ground. When frightened, they run up the trunk of a tree and are lost in a moment. It is very pretty to watch two squirrels playing. They run up and down together, and turn this way or that at the same instant. You cannot tell which is following the other, for they seem to run about more like one animal



Fig. 8.—SQUIRREL.

The ear-tufts shown in the picture disappear in the summer.

than two. The Squirrel springs from bough to bough with great ease. When he is on a solitary tree, or at the edge of the wood, and wishes to come down quickly, because he is frightened or for any other reason, he leaps out into the air and spreads his tail. The Squirrel's weight is very small, and the surface which he spreads is rather large, so that he comes down almost as gently as a falling leaf. When he reaches the ground he is off to some place of shelter in a moment. The bushy tail of the Squirrel

serves another purpose too. When the animal goes to sleep, it curls itself up, and wraps its tail round about its body, and so keeps perfectly warm. Squirrels build warm nests in trees, like Birds, and bring up their young in the nests. When the young Squirrels are strong enough to run about, the mother takes them out with her,

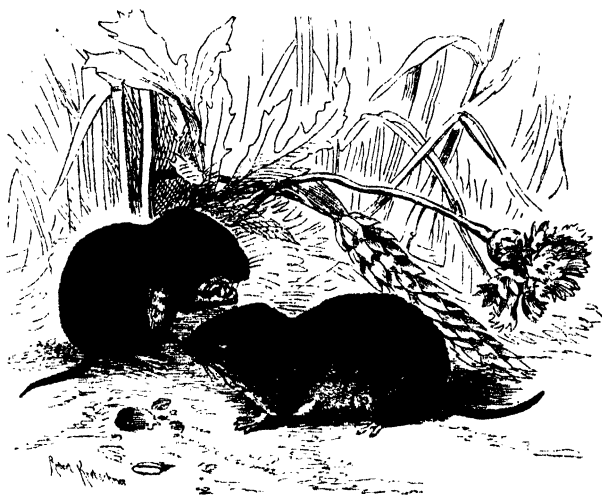


Fig. 9.—FIELD VOLES.

and shows them how to find their own food. If the mother wishes to call them, she makes a sort of squeak or bark, and the young ones run to her directly. Squirrels are fond of storing up nuts and acorns and other seeds in holes. Sometimes the Squirrel forgets the place, and never comes back, but the seed sprouts and grows into a tree. Squirrels thus plant trees up and down, without intending it. The belongs to the same order of Mammals as the

Rabbit, Rat, Mouse, and Voles. This is the order of *Gnawing animals*.

Field Voles.—The other day I found an old thorn-tree which had a large hole near the root. In this hole were hundreds of little nuts or pips, of hawthorn. No doubt they had grown upon that very tree, for there were no others near. Every pip had a tiny round hole drilled through the hard shell. Some small animal must have done it to get at the kernel of the pip. What animal could it have been? It was a Field-mouse. The Field-mouse is not the same as the Mouse which lives in our houses. Its tail is not long, and round, and scaly, like that of the true Mouse, the eyes and ears are much smaller, and it is not so quick in its movements. The Field-mouse is called the *Field-vole* by naturalists. It has a sort of first cousin in the Water-vole, or Water-rat.

Shrews.—There is another small creature which is sometimes called a Field-mouse, but which naturalists distinguish as the Shrew. It is not really much like the Voles or Mice, except in size and colour. It has a long and slender snout; the tail is rather short, and ends in a brush of hairs. The teeth are pointed, and quite unlike those of a Mouse or Vole; they are tipped with red. The Shrew feeds upon Insects and Slugs.



Fig. 10.—SHEWS.

Just as there are Water-voles and Land-voles, there are Water-shrews and Land-shrews.

Other creatures besides Voles are fond of nuts. The Squirrel is one of these. But the Squirrel rasps away the

small end of the nut, and then splits it with its strong teeth and drops the broken pieces. You can see at a glance whether it was a Squirrel or a Field-vole which ate the kernel.

Bats.—Here is the skin of a Bat. You see that the body is covered with soft fur. The ears are very big ;



Fig. 11.—BAT FLYING.

indeed, in the Long-eared Bat they are nearly as long as the whole animal. They are thin and bare, so that they are nearly transparent. The Bat is also provided with whiskers which feel the slightest touch, and it can smell very well, so that it easily gets about in the dark, and finds the Insects on which it feeds. The Bat has wings of a peculiar kind, very different from the wings of a Bird. To begin with, they carry no feathers. Then the fingers of the Bat are very long, while those of a Bird are mere

stumps. Between the four long and slender fingers of the Bat's hand a thin skin or web is stretched, and this joins the sides of the body and the hind leg; there is another web between the hind leg and the tail. The thumb is short, and free from the web; it bears a claw, but there are none on the fingers.

The hind legs are short and weak. The toes have small claws which are chiefly used to hang by. When the Bat is tired, it gets into a dark corner, under a bridge, or in

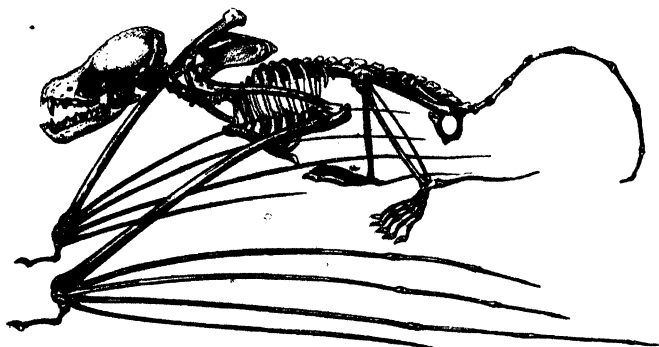


Fig. 12.—SKELETON OF BAT.

a belfry, or some such place, and catches hold with its toes. Then it folds its wings about it, and goes to sleep, with its head hanging down.

Evening is the time when the Bat begins to stir again. As soon as the sun is down, it flits about, darting hither and thither, and turning suddenly every moment. You never know where it will fly next, and it pounces unexpectedly upon the Insects which are abroad. It has often been seen to take a sip of water as it darts over a pool or river. In cold weather, when no Insects come forth, the Bat does

not leave its shelter, but sleeps for days and weeks together.

If you put a live Bat on the ground it shuffles about in the most awkward fashion. Its legs are



Fig. 13.—BAT SLEEPING.

support its weight, and it has to go on all fours. As soon as possible it gets on the wing, or else creeps into a dark corner.

Bats may often be heard to shriek to one another. Their cry is so shrill that many people cannot hear it at all. I have known a naturalist who often heard the cry when he was a boy, but could no longer distinguish it when he grew up.

LESSON II.

THE RABBIT.

WANTED:—*A fresh Rabbit, with the Skin on.*

What is Fur?—There lies on the table a Rabbit, fresh from the market. Its body is covered with brown-grey fur. What do we mean by fur? You tell me that fur is soft, warm hair. So is wool, but we do not call wool fur. If you think a moment, you will recollect that in fur there are very many delicate hairs crowded together in a small space, and that these hairs are never curly, and never lie flat, but generally stand straight out from the skin. A Dog's coat is not fur, because the hairs are coarse, and either lie flat or else curl. But the Cat, and the Mouse, and the Mole, and the Shrew, all have fur like the Rabbit. Velvet is rather like fur, and in velvet too the threads are made to stand straight up. In fur there are two sizes of hairs, coarse and fine. The coarse hairs are sunk more deeply in the skin, and stand out beyond the rest. They are useful to keep off rain, and to prevent the fine hairs from getting matted together. The fine hairs are crowded as close as possible, and nothing could be better as a defence against cold. We often find ten or twenty fine hairs to one coarse hair.

Colours of Animals.—Tame Rabbits are of many colours—black, white, brown, grey. Wild Rabbits are nearly all of one colour, a sort of sandy grey. Why this difference? I think it is because among wild animals one particular colour is safer than any other. If the creature lives in sandy places, it is much to its advantage to be of a sandy colour, for then its enemies do not see it so easily or

so far off. But tame animals have no enemies to speak of, and it does not signify of what colour they are. A black Rabbit would have a poor chance on a sand-hill in a wild country. The Eagle, Kite, or Stoat, would see him wherever he went, and would look out for a chance of catching him far from his hole. A black Rabbit would be like an unarmed man carrying a lantern by night in a country full of robbers. It is only in a peaceful country that an unarmed man would dare to carry a lantern at night, and it is only in safe hutches and close to houses that black or white Rabbits can live long.

Eyelids.—The eyes of the Rabbit are protected by three eyelids. The upper and lower eyelids are like our own, but the third is drawn over the eye from the inner corner next to the nose. If I catch the edge of the third

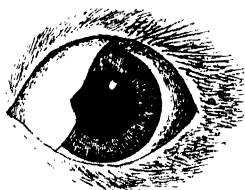


Fig. 14.—THIRD EYELID OF RABBIT.

eyelid with a pair of forceps I can easily draw it across the eye. This third eyelid is the one commonly used by the Rabbit in winking. We have no third eyelid, but we have a sort of fleshy wart at the inner corner of the eye next to the nose, which corresponds to the

third eyelid. Monkeys, Cats, Dogs, Sheep, Cows, and Whales have no third eyelid, but most other Mammals have.

Ears.—See what long ears the Rabbit has! But they are not quite so long as the Hare's ears. I suppose that these long ears enable the timid Rabbit or Hare to catch the most distant sound of danger. Rabbits often stand up on their hind legs, and move their ears this way and that, to hear whether anything is stirring.

Lips.—Notice the Rabbit's lips. The upper lip is split so as to show the front teeth. What is that for? The side of the upper lip carries a number of long hairs or whiskers. You recollect that a Cat has whiskers too. What is the use of whiskers?

Teeth.—If you open the Rabbit's mouth you will see the teeth. The front teeth are long and curved, and have a chisel edge. The grinders are flat, and set far back in the jaws, so that there is a space between them and the front teeth. How many front teeth are there? If you are not very careful you will make a mistake in counting them. Each upper front tooth is divided along its whole length by a groove, so that it appears double. Besides the two long upper teeth which show so plainly in front, there are two others

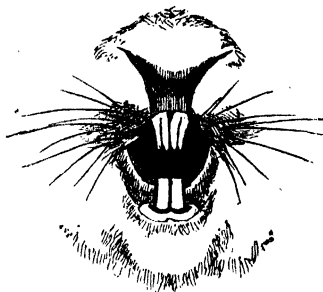


Fig. 15.—FRONT TEETH OF RABBIT.

close behind, and these you will miss if you do not look out for them. There are really four upper front teeth, and two lower front teeth. That makes six front teeth altogether, of which only four can be seen from the outside of the mouth.

Inside of the Mouth.—Do you notice the patch of hair along the inside of the cheek? It is a long, narrow strip of hairy skin which ends just where the grinders begin. How funny it must be to feel a bunch of stiff hairs on the inside of the mouth! If you look carefully at the Rabbit's tongue you will find a white patch upon it,

where the skin is much thicker than elsewhere. Now look at the roof of the mouth and see if there is anything uncommon there. It is very stiff, and hard, and uneven. A number of short ridges run across it. What a singular mouth the Rabbit has! Why should it be so different from

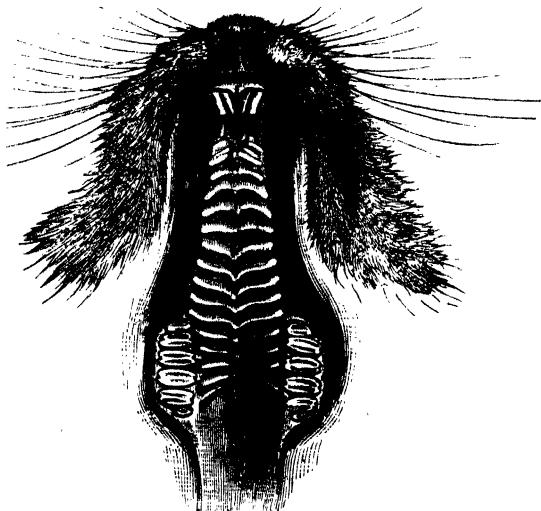


Fig. 16.—ROOF OF RABBIT'S MOUTH.

the mouth of other animals? Depend upon it, there is a reason which we can find out by observing and thinking.

Gnawing.—Everyone who has seen much of Rabbits knows that they are gnawing animals. If you keep a Rabbit in a wooden hutch, it gnaws the bars. If there are Rabbits in your shrubberies, they gnaw the bark and young wood, and often kill trees in this way. Hares, Rats, Mice, Guinea Pigs, and Voles are gnawing animals

too. If *you* were to take to gnawing trees, you would find out before long that your mouth was not well suited to the work. Your lips would soon get sore from rubbing against the rough bark. Splinters would run into your



Fig. 17.—SIDE VIEW OF RABBIT'S MOUTH.

tongue and cheek. But the Rabbit's mouth is far better adapted for gnawing. The front teeth stand out a long way from the gums, and the upper lip is split, so that it can be quickly drawn back out of the way. The hairy patch protects the inside of the cheek. The tongue is protected by the thick skin on its upper surface. The palate, or roof of the mouth is protected by its thick, horny ridges. The Rabbit can gnaw all day and take no harm.

Mastication.—The back part of the Rabbit's mouth is quite different from the fore part or gnawing chamber. The fore part is like a joiner's workshop; the back part is like the little parlour behind where the joiner eats his dinner. In the back part of the Rabbit's mouth are the grinding teeth, and the part of the tongue which tastes the food; and here most of the *saliva* is poured out—that is, the fluid which moistens the food, and prepares it for being swallowed. When the Rabbit has done the rough gnawing work in the fore part of his mouth, he passes all the eatable part of the food into the chamber behind, which has a soft and sensitive skin, and there he masticates it at leisure. In order to remember the back part of the Rabbit's mouth, and what is contained in it, we may call it the *masticating chamber*. What do we mean by mastication? Grinding the food small, and mixing it with saliva. Saliva is the fluid which pours into our mouths when we eat. Even if we *think* of something very tasty, the saliva often flows into our mouths. This is what we mean when we say that *our mouth waters*.

More about Teeth.—The Rabbit's teeth have a great deal of hard work to do, and they must be prevented from wearing out. The front teeth have to be kept sharp, like a carpenter's chisel, or they would soon be useless. All this is provided for by nature. *The teeth of the Rabbit never stop growing*. Our own teeth grow till they have got to their full size, and then they stop. If a tooth wears out, or decays, or has a bit broken off, it can never be mended naturally. But if it is a milk tooth, or tooth of the first set, it will fall out some time, and be replaced by a new and perfect tooth. If it is a tooth of the second set, it must stay as it is—worn out, decayed, or

But the Rabbit's teeth, all of them, keep on growing below. If they wear out at the top it does not signify, for they do not get smaller or weaker. Nor do they get blunter, which is a very odd thing. How convenient it would be to the carpenter if he had a box of chisels and saws which never wore out, and never needed sharpening! The Rabbit has such a set of tools in his teeth. Each tooth consists of a very hard substance called *enamel*, and a softer substance called *dentine*. Some of the dentine is harder than the rest. Now I will try to explain to you how the teeth keep sharp, and I will speak only of the front teeth at present, because they are easier to understand. The very hard enamel is set along the front surface of each of these teeth, and forms a thin layer, which comes to an edge at the end of the tooth. Behind the enamel is the hard dentine, and behind this the ordinary soft dentine. When the Rabbit gnaws hard things, such as wood, the soft dentine soon wears down; the hard dentine wears more slowly. The enamel is so extremely hard that it wears down still more slowly, though it has most of the work to do. Thus the grinding surface of the tooth comes to slope backwards; and, however much it is worn, the hard enamel stands out beyond the dentine, and the hard dentine stands out beyond the soft. A carpenter's plane-iron is made of hard steel in front, and of soft iron behind, so that it keeps sharp a long time; but no one can make a plane-iron or a chisel which will *never get shorter*, like the Rabbit's tooth.

The grinders of the Rabbit keep on growing too, and never change their shape, however old they are, and however much work they may have done. But now I must tell you of one drawback to this beautiful case of tools in

the Rabbit's mouth. If one of the teeth is broken, the whole case is liable to get out of order. The opposite tooth will then go on growing longer and longer without being worn down, for there is no tooth to meet it. In time this tooth grows so long that it curves out of its proper place, and then it gets in the way of its neighbours. These do not meet properly, and are no longer worn down; so they, in turn, grow too long. At last all the teeth in the Rabbit's mouth get out of shape, and the poor animal cannot masticate its food at all.

Feet and Tail.—The Rabbit has claws on its feet. How many toes are there? Four in each foot. Yes; but if you look closely, you will see a small toe on the inside of each fore foot. The hind leg is longer and stronger than the fore leg, and has only four toes. The Rabbit has a ridiculous little tail, which is white on the under side. When a number of Rabbits scurry away to their holes, it is very amusing to see their white tails bobbing up and down. Perhaps this serves as a warning to other Rabbits which are behind, and farther from a place of refuge, that they must be off too. Roedeer have white hair on the haunches, which may be useful as a mark by which the young can track the mother in woods and thickets. Hares run in the open, and show no white behind.

Rabbits drum on the ground with their hind legs as a signal to their fellows. On a still summer evening the noise can be heard a long way off, and you can hear Rabbits drumming far underground. They never scream, except when in great pain.

Burrows.—Rabbits are very fond of burrowing. They work out a sort of underground village with many passages, which is called a *Rabbit-warren*. Some of these

passages lead to the holes at the surface of the ground, and some to snug little nests, where the mothers keep their young ones. The nests are made warm with grass, and leaves, and bits of fur, which the Rabbit tears off from her own breast. The Rabbit likes sand to burrow in, because it is loose and easily thrown out. You will see many Rabbit-warrens where there are sand-hills along the sea-shore. Why does the Rabbit burrow in the ground? To avoid its many enemies. These are chiefly Weasels, and Stoats, and Cats, and large Hawks, and Owls. But many other hunting animals are only too glad to pounce upon a Rabbit whenever they get a chance. Why does the Rabbit make many passages and many holes to the surface? In order that the enemies which pursue it underground may lose their way in the dark, while the Rabbit, who knows every turn, may escape and get into another burrow. If there were only one way out, a single Ferret would be able to strangle all the Rabbits in the warren.

Use of Whiskers.—The Rabbit scratches out most of the sand and earth backwards with its hind feet, which, you will recollect, are long and very strong. How does the Rabbit find its way in the dark passages of the warren? By feeling with its long and sensitive whiskers. The Rat, and the Mouse, and the Cat use their whiskers in the same way, and all these animals are very clever at finding their way in the dark. Most quadrupeds have some long hairs about the mouth; but those which run about in dark places have them very long and stiff, and standing out from the sides of the face.

Use of Fur.—Animals with long whiskers are often covered with fur. This looks as if fur, like whiskers, might be particularly useful to creatures that make their

way underground, or wriggle into narrow places ; and I believe that this is actually the case. Fur is not only a capital protection against cold, but it will also throw off mud and water, and keep the animal clean and dry. It is, therefore, an excellent covering for creatures which have often to brush against wet and muddy objects, or which live in damp caves, where things take a very long time to dry. The Mole spends nearly all its time underground, but its fine close fur never gets dirty. Rabbits spend much time in cleaning their fur, and perhaps Moles do the same.

Native Countries.—The Rabbit is not native to England. All our Rabbits have bred from Rabbits brought from other countries. The Rabbit is really native to Spain, Italy, North Africa, and Arabia, but he has been brought by man to other countries.

Hares.—Hares are very like Rabbits, but larger. The ears are rather longer than in the Rabbit, and tipped with black. The Hare never burrows, but lies on the ground. In summer it chooses shady places, but in winter it lies in open fields, where it gets all the sun it can. The Hare scratches up a rough lair, or bed of leaves and grass, which is called its *form*.

LESSON III.

BIRDS.

WANTED:—*A Bird's Wing. The Bones of a Wing, laid out on black card or wood. Eggs of various Birds.*

Birds have Feathers and Wings.—Birds are the only animals which have true feathers. Mammals never have feathers, but only hair. Most Reptiles and Fishes have

scales. Birds have wings, with long feathers, called quills, in them. The wings are to fly with, but some Birds which have wings never fly. The common Fowl flies very badly, and only for a short distance. The Ostrich never flies at all. Do you know any other Bird which cannot fly? Some one says the Goose; that is because you have only seen tame Geese, which have had their quills cut or pulled out. The *Wild* Goose is a splendid flier, and can easily fly a hundred miles at a time. Wild Geese often fly in flocks, high up in the air, so high that they look like little specks.

Bills.—Birds have hard, horny bills, instead of lips, because they have to pick up everything they want with their mouths. We have hands; Cats and Dogs have very useful fore-paws; Cows and Horses have no paws; indeed, they would not know what to do with them if they had, for the grass upon which they feed does not need to be caught or carried. The Bird requires to catch and carry such things as seeds or Insects, but it has no hands or fore-paws; it has wings instead, and wings cannot be used for grasping. So the Bird's mouth is made stiff and hard, and forms a horny bill, which often ends in a point. Such a bill is almost as useful for picking things up as a pair of hands.

Neck.—The Bird has a long neck, so that it can pick up objects from the ground without stooping much. It can reach every part of its own body with its bill.

Feet.—The Bird's feet and the lower part of its legs are usually bare of feathers, and covered only with scales. This is convenient for a creature that often hops about in wet and dirty places; water or mud will not cling very long to the Bird's feet. But some Birds which do not

run much on muddy ground, have feathers down to their toes. Owls have feathered feet, so have Grouse. Birds are very careful to keep their feathers dry, and you seldom see a Bird wet, even on a rainy day. They spend much time in cleaning and smoothing their plumage.

Bones of the Wing.—Here are the bones of a Bird's wing. You see the long bones, which are like those of our own arm. Next come two wrist bones. The bones of the

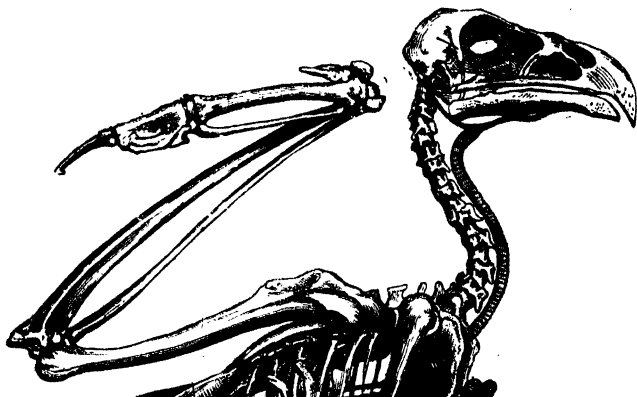


Fig. 18.—BONES OF A BIRD'S WING.

hand are so altered that it is not easy to make them out. There are really a thumb and two fingers, but these are mere stumps, which have lost many of their joints, and have become almost immovably fixed. A tough skin is spread over these fingers, and the quills of the wing are stuck into the skin. This is a hand which can grasp nothing; it cannot be used for running like the forepaw of a dog; everything else has been given up in order to make it as useful as possible for carrying quills.

Nevertheless, we can see that the wing-bones correspond to the arm and hand-bones of our own bodies, and to the bones of the fore-paw of the Dog.

How a Bird flies.—When a Bird flies it beats the air with its wings. It is the down-stroke of the wing which raises the bird in the air. You know that when you jump you press your feet hard and suddenly against the earth, and as the earth is firm and does not give way, your body is forced to give way and rises into the air. In swimming we strike the water with our hands and legs, but the water gives way very easily, and we cannot push against it so well as we can against the solid earth. Air gives way even more than water, and hence few animals can move in the air at all. Birds can do so, because their wings are very broad and strong, and can press a great deal of air very hard at the same time. When the air is pressed downwards very hard and very suddenly, the bird's body rises upwards. All the effect of the stroke would be lost if the upstroke were exactly like the down-stroke; one would raise the bird's body in the air, and the other would bring it down again. But you can see for yourselves that the Bird's wing is arched, and the hollow side is downwards. It is a little like an umbrella, and you know how much less the upper side of an umbrella catches the wind than the under side. In a high wind we turn the upper (or *convex*) side of the umbrella to the wind, so that the wind may catch it as little as possible. If the wind suddenly catches the under (or *concave*) side of the umbrella at a street corner it strikes the umbrella with such force that it will often turn it inside out. This will help you to understand how the under side of a Bird's wing strikes the air much more strongly than the upper

side. The air cannot escape so quickly from the concave side as from the convex side.

The wing is at the same time a kind of oar, and the Bird travels by rowing with its wings. The quills of a live Bird are not set stiffly in the wing, but are movable. Each quill can be swung round a little way, like one of the bars of a venetian blind. During the up-stroke the quills are set so that air can easily pass between them; but during the down-stroke they form an unbroken surface, which strikes the air with the greatest force possible.



Fig. 19. — SEPARATION
OF THE QUILLS IN A
BIRD'S WING.

(From a Photograph by
Muybridge.)

How fast the Wings move.—

When many strokes are made quickly one after another, the Bird rises in the air. You can hardly imagine how quick the strokes of a Bird's wing are. The Heron is believed to flap its wings more slowly than any other Bird which lives in this part of the world. I once counted the number of flaps of a Heron's wing, and found them ninety in a minute. You could not move your arm up and down so fast for half a minute. Most Birds flap their wings far faster than the Heron, sometimes so fast that the wing cannot be seen at all.

I have not told you nearly all that is known about the flight of Birds, because you are not yet able to understand it fully. Wings are very ingenious machines, much harder to understand than steam-engines or watches.

A Bird does not rise in the air because it is lighter than the air. It is not at all like a balloon. We see

that when a Bird is shot, it falls almost as fast as a stone.

Flight of Sea-gulls.—Sometimes we see Birds fly very fast, without any sign of effort. Sea-gulls often follow a steamer at sea to pick up bits of biscuit thrown to them by the passengers. I have been on the deck of a fast steamer, travelling nearly twenty miles an hour, and have seen the Gulls follow close astern for hours together. They do not flap their wings, but seem to sway and lean first this way and then that, and travel as smoothly and easily as if they were merely floating in the air. But they must be working hard all the time, or they could not go so fast.

Eagles and Hawks.—Some Birds which live by catching other animals and eating them are called Birds of Prey. Eagles, Owls, and Hawks are Birds of Prey. They are generally strong and swift, and have a pointed beak, bent down at the tip, and sharp claws. Eagles



Fig. 20.—SPARROWHAWK.

destroy lambs, and are hunted down by shepherds. There are hardly any Eagles left in England or Scotland. Owls prey upon Field-mice and Frogs. They swallow them

whole, and afterwards throw up the skin and bones, which are not good for food. In a cave, or roof, or hollow tree inhabited by Owls, thousands upon thousands of bones of small animals can be picked up. Sparrowhawks prey mostly upon small Birds. Where there are many Hawks about, there are hardly any Sparrows, or Tomtits, or Larks.

Nests and Eggs.—Birds lay eggs, and when the eggs are hatched, little Birds come out of them. Most Birds build nests to keep their eggs safe and warm, but some lay their eggs on the ground almost anywhere. A Thrush's nest is very carefully built, snug, and comfortable. A Raven's nest is nothing but a loose heap of sticks. Some Birds hide their nests very carefully in hedges or tree-tops, or hollow trunks.

Lapwings.—The Lapwing, which is also called the Peewit, lays a few eggs together on the bare ground, and we sometimes run a risk of treading upon them, when walking upon moors or wild pastures in spring-time. As soon as the young Lapwings are hatched, they begin to run about and seek their food. The hen-bird watches them very carefully until they can fly. If you come near the little ones, the mother screams, and makes you look at her. Then she flies about very slowly, and keeps settling on the ground as if she were unable to fly properly. You wonder what is the matter, and think that it would be easy to catch her. If you try, she flutters away almost as if her wings were injured. Then you run a little faster, but the Bird still keeps just out of reach. At last you find out that it is all a trick, but by this time you have forgotten where you first saw the Lapwing; the careful

mother has managed to lure you away from her helpless brood. No doubt she deceives Birds of Prey and hunting animals of all kinds in the same way. The Lapwing is so named because she *lops*, or droops her wing, when practising this trick. The name *Peewit* is intended to imitate her cry. Young Lapwings are coloured brown and yellow, and look so like the heather and withered grass among which they live, that you can



Fig. 21.—LAPWING.

hardly tell that they are alive except by seeing them run about, or by catching the glitter of their large, bright eyes. When an enemy approaches, the young Bird lies quite still, and is then very hard to distinguish. What are the worst enemies of young Lapwings? Hawks, I believe.

Kingfishers.—The Kingfisher lays its eggs in holes in the banks of rivers. It makes a rude nest of the bones of fishes, to prevent the eggs from rolling out. The hole slopes upwards to the nest. Why is this? I think it must be to prevent the hole from getting filled with water during heavy rain, or

when the river is flooded. In country places you may often see the Kingfisher flitting about the bushes on the banks of a river. It is a beautiful Bird, with blue and seagreen plumage and a chestnut breast. Its beak is long and strong, and its wings and tail are short.



Fig. 22.—KINGFISHER.

It dives into the water after Fishes, or Water-insects, and generally comes up again with one in its mouth. The Kingfisher darts down into the water very suddenly, and the Fish has no time to escape. It is hard to catch a Minnow or any other little Fish in this way, and the Kingfisher would catch nothing at all, if it were not able to dart into the water like an arrow shot from a bow. When the Kingfisher has caught a Fish, it tosses it up in the air, and then swallows it head foremost. The King-

fisher's eggs are white and nearly round, so are the Owl's. Both are laid in safe places, where they cannot roll.

Shapes of Eggs.—Some Birds' eggs are wide at one end, and rather pointed at the other. The Guillemots and some other Sea-birds lay eggs of this shape. What is the reason? It is because they lay their eggs on rocky ledges where they are liable to be blown about by the wind. An egg that is broad at one end and narrow at the other will

not roll far, but will roll round and round. Try to roll a pear upon the table. You will find that you can hardly make it roll across; it merely rolls round in a circle. But a Fowl's egg can be rolled across the table, though not in a straight line; the two ends are not so different in shape



Fig. 23.—GUILLEMOT.

as those of a Guillemot. Sandpipers, too, lay large eggs which are pointed at one end. They are set in a circle in the nest, with the small ends pointing inwards, and thus they pack into the smallest possible space, and are easily covered by the sitting Bird.

Colours of Eggs.—Eggs are of many colours. The Owl lays white eggs; the Hedge-sparrow bluish-green eggs; Sea-birds generally lay speckled eggs. I believe

that the eggs are sometimes coloured in a particular way to make them less easily seen. The eggs of the Common Tern, which are laid on sand, are sand-coloured. I have sometimes walked about on rocks by the seaside where eggs of Sea-birds were lying, and have found it impossible to avoid treading on the eggs now and then, for the speckled



Fig. 24.—EGG OF GUILLEMOT.

eggs looked almost exactly like the rocks on which they were lying.

What are the enemies which are deceived by the speckled eggs? There are many of them. Some, like the Weasel, are small Quadrupeds; others, like the Magpie, the Jay, and the Crow, are Birds.

If a Bird lays white eggs, you may be pretty sure that they are not much seen. Either they will be laid in a deep hole, or in a deep nest, or they will be covered up by the sitting Bird.

Solan Geese.—There is one of the Sea-birds which dives even more swiftly than the Kingfisher. This is the Solan Goose, a big white Bird which lives on the coast, and gets its living by fishing. There are hardly any Solan Geese left in England now, but there are plenty in some

parts of Scotland. When the Solan Goose sees a Fish, he darts down from a great height, and strikes the water with so much force that a shower of spray flies up twenty feet or more into the air. Perhaps I ought to tell you that the Solan Goose is not a Goose at all, but a kind of Pelican.

Rookeries.—Some Birds are social, and live many together in a sort of village. Can you mention an instance?



Fig. 25.—GANNET, OR SOLAN GOOSE.

A Rookery. Yes, that is a sort of Bird-village. No doubt the Rooks like company, and I daresay that they and their nests are safer for being kept together. All animals which live in societies must have some sort of laws, to prevent the doing of certain things which are found to be mischievous to others. I believe that Rooks have laws of their own, but what these laws are I do not know. Sometimes a pair of Rooks are not allowed to join the rest. Whenever they

come near, they are buffeted, and driven away. Sometimes the Rooks will not allow a nest to be built in a certain tree, and if the nest is begun, the others come and pull it to pieces. A friend of mine once saw a young Rook killed by its companions. As they were flying out together, one Bird flew up above the rest, and suddenly came down with great force, and drove its beak through the head of the young Rook, which fell dead to the ground. I think that the poor Rook must have done something which the others thought worthy of death. Rooks seek their food in the fields, and live upon Insects, which they dig up with their strong beaks. It is believed that they also feed upon grain. Sometimes Rooks build little collections of nests, like small outlying villages, away from the towns, which are the large Rookeries. They all come back to the towns, or large Rookeries, in winter. All the Rooks which we see flying about do not belong to Rookeries in the neighbourhood. Some are wanderers, on their way to other parts of the country, or even to other countries.

Rooks seem to be fond of company, for they often go about with quite different Birds, such as Starlings, or Jackdaws. But I am not certain that it is the Rooks who seek the company of the other Birds. Perhaps the Starlings and Jackdaws follow the Rooks about. Sparrows are fond of building under Rooks' nests.

Birds of Passage.—I daresay you all know that there are Birds which are only to be seen in England during the summer. Can you mention one or two of these? The Swallow is one, the Nightingale is another, the Cuckoo is a third, the Corn-crake is a fourth. Well, here are examples enough, but plenty more could be named. Then there are Birds which come to us only in the winter. Can you

name some? Ah, you are not so ready with these! I must help you. There is the Woodcock for one, and the Fieldfare for another. These Birds come in autumn, and



Fig. 26.—SWALLOW.
Comes to us in Spring.



Fig. 27.—NIGHTINGALE.
Comes to us in Spring.

generally go away before summer. Many Birds remain with us all round the year. Do you know of any such Birds? The Blackbird, Thrush, Starling, Robin. Yes, that will do. I must tell you, however, that these Birds are not all of them quite so settled as you might think.

Naturalists believe that, though we have Robins with us all round the year, our winter Robins fly north in spring, and their place is taken by other Robins which come to us from the south.

Now let me see if you can tell me why Swallows and other birds *migrate*, or pass from land to land at certain seasons of the year. You tell me that when winter is



Fig. 28.—Cuckoo.
Comes to us in Spring.

coming on they fly to warmer countries, and then in spring they return to enjoy our pleasant summer. I think that Swallows do not fly away southward in autumn because they are afraid of the cold, for they are hardy little things. I believe that they stay as long as the small flies upon which they feed are abundant, and go away when the cold checks the numbers of the flies. Many of these flies are hatched from little worms which live in water, and they do not change into flies unless the weather is tolerably warm. You know how many swarms of small flies we see on hot evenings, and how scarce they are in cold weather. The fly-eating Birds generally migrate southwards in

winter. Birds which live on berries and seeds are not

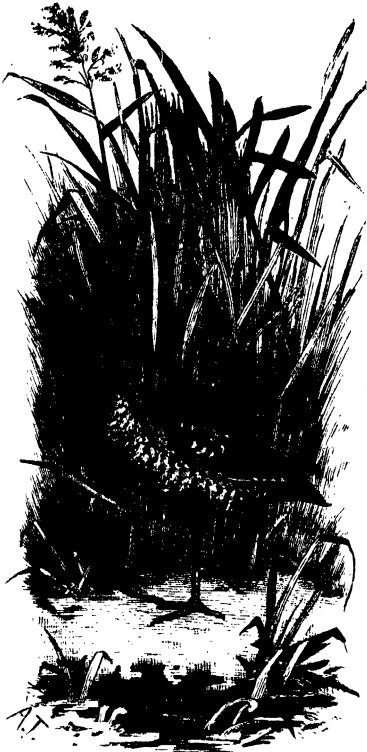


Fig. 29.—WOODCOCK.
Comes to us in Autumn.



Fig. 30.—FIELDFARE.
Comes to us in Autumn.

obliged to migrate from England when winter draws near, for they can get food even in cold weather. •

Hard-billed and Soft-billed Birds.—Let me point out a way of telling the Insect-feeding Birds from those which live upon seeds. The Birds which live upon seeds

must have hard and strong bills, for the seeds are often hard to crack. You know that the Canary, which we keep in cages, is a seed-eating bird. Look at its bill, and you will see that it is thick and strong. The Canary is a kind of *Finch*, and all the other Finches, such as the Goldfinch, the Bullfinch, and the Chaffinch, are seed-eating birds with strong bills. So are the Buntings. Such birds as the Finches and Buntings can stay in England all round the year. The Insect-feeding Birds have soft bills, and these

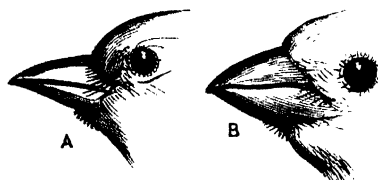


Fig. 31.—BILLS OF FINCH (A), AND BUNTING (B).

are sometimes very slender. Many kinds of soft-billed Birds are obliged to migrate in autumn for the sake of food.

Gizzards. — Birds which feed on seeds and grain have a curious mill in their bodies, called a gizzard. It is fleshy outside, but has a very tough lining, and contains a number of small stones. All the food of a grain-eating Bird passes through the gizzard, and gets ground up there. The Bird has to swallow fresh stones now and then, because the old ones wear away, and pass out of the gizzard, and are lost. If you hold a Pigeon to your ear when it is digesting its food, you can hear the grating sound of its gizzard.

Snowstorms and Famine.—Birds which stay the winter in England manage pretty well, except when the snow lies long on the ground. Snow covers up the loose seeds, and prevents the worms from coming out of their holes. You know that there are many Birds, like the Thrush and Blackbird, which live almost entirely on worms, and

starve by thousands when the ground is covered with snow, or kept hard by frost for weeks together, as it is in severe winters. The grain-feeding Birds are hardly better off. Even if they find a few berries or chance seeds they cannot feed upon them, for after a long spell of snowy weather they have no stones or gravel left in their gizzards, and cannot pick up fresh ones, so they cannot grind their scanty supply of food. A long snowstorm brings many hardships upon wild animals. Gulls, and Hooded Crows, and Sky-larks, which naturally love quiet and solitary places, will then venture into towns in search of food; and even the timid Hare will creep into the gardens of country-houses, and gnaw the shrubs.

LESSON IV.

INSECTS.

WANTED:—*A large Beetle, a Butterfly and a Bluebottle Fly. Divide each Insect into head, thorax, and abdomen. Pin or gum these, back downwards, to a card, with small spaces between. Cut off the wings, and arrange them at the sides of the thorax. The legs may be left attached to the thorax.*

Parts of an Insect.—We have before us three Insects, divided so as to show the three principal divisions of the body—head, thorax, and abdomen. The head carries the eyes, the antennæ, or feelers, and the mouth with its biting or sucking organs. Inside the head is the brain, which feels, and guides all the movements of the body. The thorax carries the wings and legs. How many wings

has the Butterfly? Two on each side. How many wings has the Fly? One on each side. How many has the Beetle? Two on each side; but the fore pair are not like the hind ones. They are hard and stiff, and of no use in flying. These are called *wing-covers*. They overlie the hind wings, and protect them when the Beetle is creeping or burrowing in the earth, or resting. How many legs has the Butterfly? Six. How many has the Fly? Six. How many has the Beetle? Six. All full-grown Insects have six legs, neither more nor less. They may have two pairs of wings, one pair, or none. The abdomen never carries legs or wings; it contains the digestive organs, and in female Insects may also contain a vast number of eggs.

Hard Skin.—The body of an Insect is usually covered with a hard skin. This becomes so hard in the Beetle that we might almost call it a shell. In the Bluebottle it is smooth and shining. In the Butterfly it is covered with hairs, and feels soft and flexible, but it is tolerably tough. The skin is folded inwards at nearly regular intervals. The folded-in parts are thin and flexible; the exposed parts, which can be seen from the outside, are thicker—sometimes much thicker. These folds are called the rings of the body, but they are not *separate* rings. I can take a sheet of paper and fold it across several times so as to form sharp sunk folds, like those of an Insect's skin. If I now bend the folded paper round into a tube, it will be rather like the outside of an Insect's body.

Many Kinds of Insects.—There is an immense number of different sorts of Insects. No one person knows them all; perhaps no one knows so many as a tenth of all the living Insects. If you were to spend five minutes

upon each, and work twelve hours a day, it would take you several years to examine every different sort.

Some Insects live in earth, many on trees; some in seeds, many in grass, some in water. A very few have been found alive at the bottom of the sea, but these may have been carried down by rivers.

The wings of some large Butterflies would cover a dinner-plate. Many Insects are so small that they cannot be seen without a magnifying glass.

Shapes of Insects.—Some Insects have very odd shapes. There is a large foreign Beetle which is nearly as flat as a leaf. It creeps about under dead fallen trees. Some are round like a gooseberry. Many have legs longer than their bodies, or horns of curious shapes, or great boring tubes, which look like tails.

Food of Insects.—Some Insects feed upon living animals, which they hunt and kill. Most of them feed upon plants. Many are fond of the sweet juices found in flowers.

Changes of Skin.—Insects change their skin several times in the course of their lives. The hard skin will not stretch or grow, so a new and soft skin forms beneath it from time to time. The new skin is a good deal larger than the old one, and is creased or wrinkled all over. When the time for a change of skin has come, the old skin cracks along the back, and the Insect creeps out. The new skin is then fully formed, but soft and flexible. It soon swells out and hardens, and then the Insect is provided with the extra space which it requires inside its body. All the muscles have to be loosened from the old skin and fixed to the new ones; so it is not surprising to find that the Insect is generally sluggish, and rests as much as

possible for a few days before moulting—that is, changing its skin. When Insects have got their wings they are full-grown, and change their skin no more.

Larva and Chrysalis.—Insects generally begin life as soft-bodied Grubs or *Larvæ*. Afterwards they become



Fig. 32.—COCHINEAL INSECT UPON CACTUS PLANT.

motionless, and rest for a time in a rounded case, which is often covered with silk spun by the Insect itself. resting and motionless Insect is called a *Chrysalis*.

When the Chrysalis-time is over, a winged Insect usually comes out, such as a Beetle, or a Moth, or a Butterfly. Some Insects never pass through a Chrysalis stage, but run about all their lives.

Useful Insects.—A few Insects are very useful to us. The Bee makes honey and wax. The Silkworm spins silk for its cocoon, and this can be unwound and made into a very valuable glossy thread. The Cochineal Insect contains a red dye, which is much prized.

Mischievous Insects.—I am sorry to say that there are far more mischievous than useful Insects. Flies and Gnats plague us a great deal in hot weather. The Tsetze-fly destroys cattle and horses in one part of Africa, so that these animals cannot live there at all. Small Clothes - moths eat woollen things of all

kinds when they are put away in drawers or cupboards. The Weevil, a little Beetle, eats and spoils a great deal of corn. The grub of the Daddy-long-legs, a kind of two-winged Fly, destroys grass by gnawing its roots. The



Fig. 33.—LARVA, CHRYSALIS AND MOTHS (MALE AND FEMALE) OF SILKWORM.

The Chrysalis is shown both in the cocoon, and taken out of it. One of the larvæ is beginning to spin.

Turnip-fly, a small Beetle, often eats up whole crops of Turnips and Cabbages. White Ants, which are found only in hot countries, eat wood, and paper, and cloth, and everything sweet, and all kinds of food. There are more mischievous Insects than I could mention in a long talk.

Differences between Insects and Vertebrate Animals.—The body of an Insect is put together very differently from that of a Mammal, or a Bird, or a Fish. In a Mammal, for instance, there is an outer skin, and beneath this are the muscles, or flesh, clothing the skeleton. The muscles are bands or strips of flesh fastened to the bones, and able to pull them this way or that. The trunk, and the head, and the limbs of the Mammal have each a bony skeleton inside covered with muscles. One set of bones hinged together forms the back-bone; and all these bones, which are called *vertebræ*, are threaded through by the spinal cord, which joins the brain, and sends out the nerves to various parts of the body. What is the use of the nerves? Some of them are organs of feeling. They put the brain, or spinal cord, in communication with the skin and other parts of the body. When anything pricks, or presses, or burns one of our fingers, the nerves communicate an impression to the spinal cord and brain. As soon as the impression reaches the brain, we become aware of what is going on in the finger; and then we say that we feel a prick, or a pressure, or a burn in that finger. Other nerves have nothing to do with feeling. They lead from the brain or spinal cord to the muscles, and excite them. When any muscle is excited by a nerve it shortens, and pulls the bone to which it is fastened. Such nerves might be called *nerves of motion*, in order to distinguish them from the
Below the back-bone in any Mammal

comes a large space, in which the stomach and other organs of digestion lie. On the under side of the body, in the chest, lies the heart, which drives the blood all over the body.

In an Insect things are very differently arranged. The skin is generally hard and firm, and all the muscles are fastened to it. There are no bones inside the body. If an Insect wishes to move, its muscles do not pull bones, but particular parts of the skin, such as the skin of the legs. That is the first difference which we have to notice.

In all Vertebrate animals the chief organs are placed as in Mammals. The brain and spinal cord are towards the back, the stomach and digestive organs in the middle, the heart towards the lower side (which becomes the front side in Man in consequence of his upright attitude). But in Invertebrate animals, such as Insects, the heart generally lies along the back, and the nerve-cord lies along the under side. If you turn a Vertebrate animal upside down it has the heart and stomach and nerve-cord in the same position as those of an Insect.

Breathing of Insects.

—Insects have what seems

to us an odd way of breathing. We are used to animals which breathe through the mouth, and take air into their lungs. Nearly all Vertebrate animals, except Fishes, breathe in this way. Fishes, as a rule, have no lungs, and they breathe by slits in the sides of the neck. Water is taken in by the mouth, and rushes out through these slits. The

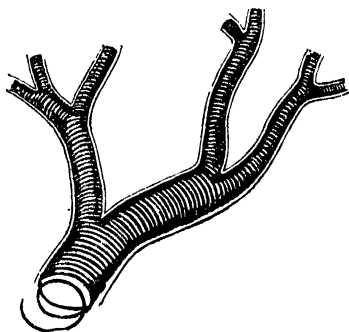


Fig. 34.—AIR-TUBES OF AN INSECT.

Fish extracts from the water some of the air contained in it, and breathes in this way, if we can call it breathing at all. An Insect takes air into its body just as we do, but not by its mouth. It has holes all along the sides of the body, and the air is made to enter at these holes. Then it passes into pipes, which break up into smaller pipes, and these again into smaller still. The air-pipes in an Insect's body branch like the gas-pipes laid in the street. You know that there is a large pipe, or gas-main, running along the street, and from this pipes are led off into each house, and smaller pipes to every room. Air is sent round to all parts of an Insect's body, in something like the same way that gas is sent to all parts of a town.

Plant-feeding Insects.—Most Insects feed upon plants. You all know that Caterpillars eat leaves, and do much mischief in our gardens and fields. But you would be surprised, I think, to find how many Insects are at work at the same time upon any tree or bush. If you spread a white cloth under a bush in June or July, and beat the bush vigorously with a stick, the Beetles and Caterpillars which were hidden beneath the leaves are shaken off and can be picked up by scores. If you examine the bush carefully you will see plenty of marks of little nibbling Insects. Some of the leaves are gnawed round the edge, some have round holes bored through them, some have galleries worked out in the thickness of the leaf, and these galleries gradually widen out as the creature grows bigger, some are eaten away till hardly anything is left except the tough ribs and veins. The bark is eaten by other Insects, and beneath the bark will, perhaps, be found yet other kinds which feed upon the soft young wood. Other Insects live upon the roots, and spend most of their lives

underground. Some live in the very heart of young buds, and devour the leaves and flowers before they can

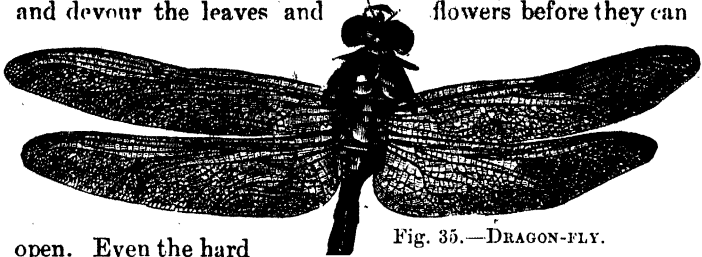


Fig. 35.—DRAGON-FLY.

open. Even the hard wood is drilled by small Beetles. When the fruit appears, an army of greedy Insects of all kinds is

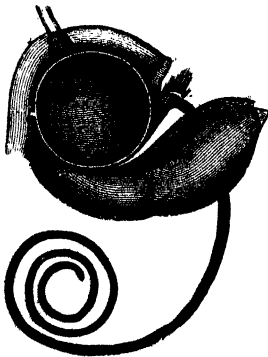


Fig. 36.—MOUTH-PARTS OF MOTH.

waiting to consume it. Little grubs make their way in as soon as the flowers fall off, and go on eating steadily till the fruit is ripe. Others, like the Wasp, bite pieces out of the most tempting part of the ripe fruit. Some prefer the seeds, and these have a great opportunity when they are so lucky as to get into a granary.

Carnivorous Insects.—There are Insects which have quite different tastes from the plant-eaters. They prefer to eat other animals, and hunt them down and kill them. The Dragon-fly is one of these *carnivorous* insects. The larva of the Dragon-fly lives in water, and devours Tadpoles and

small Water-insects. The winged Dragon-fly hawks about the fields and woods, and preys upon all sorts of weaker Insects. It has great eyes to see its victims, and large,



Fig. 37.—HEAD OF NIGHTJAR.

They often have a long, hollow trunk, or sucking-tube, which they can pass down into the very bottom of the flower, where perhaps the body, or even the head of the Insect could never get. The Insect clings to the flower with its legs, or hovers over it, and sips the sugary juice. I think our forefathers must have been thinking of these flower-haunting Insects when they talked of fairies, which sheltered under toad-stools, and drank out of the bells of the cowslips, and flew about on summer nights by the light of the moon.

Enemies of Insects.—Insects have many enemies,

gauzy wings to bear it swiftly along, and sharp, strong jaws to bite and slay.

Flower-haunting Insects.—Moths and Butterflies, and many other Insects besides, live upon the sweet juices of flowers.



Fig. 38.—SHRIKE.

and the worst of these are Birds. Many Birds feed upon nothing but Insects. The Night-jar flies about on a summer evening with its great mouth wide open, on purpose to catch Flies, Beetles, and Moths. Swallows and Swifts do the same thing by day. The Shrike prefers



Fig. 39.—PUSS MOTH AND LARVA.

The larva frightens away enemies by its dangerous look. The spots which look like eyes are only coloured patches. If touched, it shoots out coloured threads from the two tails.

Beetles and large Insects, or even small quadrupeds, such as Field-voles, and has the curious habit of sticking them on thorns, and eating them bit by bit, as it feels disposed. Rooks dig grubs out of the earth with their long bills. It seems a wonder that any Insect can escape these swift, and keen, and hungry enemies.

Defences of Insects.—But the Insect has defences of its own. Some Beetles have a skin so hard as to resist

even the pecking of a Bird's bill. Others have ugly spines, which tear the mouth of any animal which tries to swallow them. Some Moths and Butterflies, which are provided neither with hard skin, nor with spines, have a disagreeable



Fig. 40.—GEOMETER MOTH AND LARVÆ.



Fig. 41.—GEOMETER LARVA LETTING ITSELF DOWN BY A THREAD.

taste, so that no Bird will eat of them a second time. You may think it is a poor comfort to the Insect which has been torn in pieces, that it leaves a bad taste in the mouth of its destroyer. Yet it is a great advantage to any kind of Insect to be shunned by Insect-feeding Birds; and though one perishes here and there, the *race* is protected by its ill-taste.

Some Insects are well protected by their hairy skin.

All animals dislike swallowing hairy objects, for the hairs are not easily wetted, and are apt to stick in the throat. Cattle generally refuse hairy grasses. Birds generally refuse hairy Caterpillars. In certain Caterpillars the body is covered with hairs half an inch long, crowded as close as they can stick. Such hairs are not only a protection

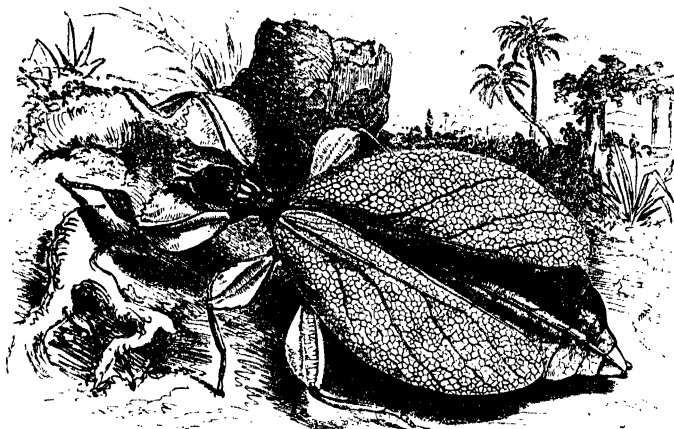


Fig. 42.—LEAF INSECT (*Phyllium*)..

against bites, which is their main purpose, but also against a blow or a fall. A hairy Caterpillar can fall from a considerable height without injury, for the springy hairs break the force of the fall.

Now and then Insects frighten dangerous enemies away merely by their threatening appearance. Some Caterpillars have ugly things like horns standing out from their bodies; others have large spots, shaded to look like eyes; and there are a few which, as they rest on a branch, look like venomous creatures preparing to bite.

Some Insects manage to escape the notice of their enemies altogether by taking a form or colour like that of surrounding objects. Many leaf-eating Caterpillars are green, and are not easily seen on the under side of a green leaf. The Caterpillars of the Geometer-moths, which are common on trees, can often hardly be distinguished from twigs. They are cunning enough to stick out from the branches to which they cling, so as to take the position as well as the form and colour of a twig. If the disguise be detected, the Caterpillar drops suddenly, and seems to have disappeared altogether. It is really hanging by a thread of silk, and when the danger is past, it climbs back to its old place. The Leaf-insect, found in the Malay Archipelago, is so like a green leaf of the Myrtle on which it feeds, that it is hard to find the Insect, even when you look carefully for it on a plant where you know it is concealed. Some of the Locusts of the same part of the world resemble dead

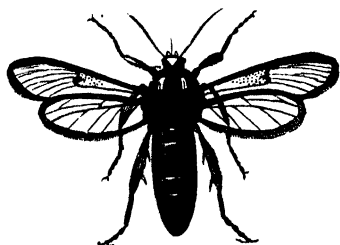


Fig. 43. — MOTH (*Sesia apiformis*)
WHICH IMITATES WASPS AND BEES.

sticks. They are careful to put their legs into a natural attitude when resting. Perhaps the most interesting of all the defences of Insects is that of *Mimicry*. An Insect, which is really harmless and good to eat, often assumes the appearance of a dangerous or ill-

tasted kind. For instance, Wasps and Bees are dreaded by other animals on account of their stings. Certain Insects, which have no sting at all, such as Flies and even Moths, make themselves as like Wasps and Bees as they can, and

are let alone in consequence. We can hardly help talking of them as if they knew what they were about, but I believe that the Insect which mimics another can no more choose a form and colour for itself than we can.

There are Insects which protect themselves by making a kind of house or nest. If it is made of materials which lie all about, so much the better, for then it escapes notice altogether. Some Caterpillars roll up leaves into a tube ;

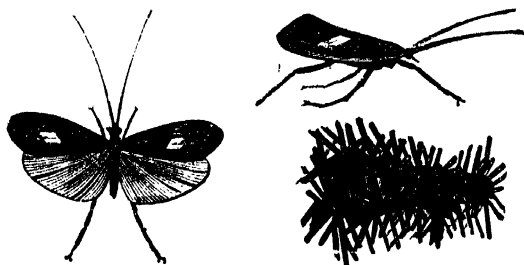


Fig. 44.—CADDIS FLY, AND CASE OF LARVA MADE OF BITS OF STICK.

Others make their cases of sand, small pebbles, or shells.

some are able to sew bits of leaves together. The Caddis-worm, which is very common in our brooks, glues together bits of stick or stones, and makes a sort of house, which it carries about wherever it goes. No doubt the Fishes take it for a heap of gravel, or a bundle of sticks, and let it alone. There are Wasps which make hollow cells of clay to lay their eggs in. But the Bees are the most ingenious of all. They first of all make wax, and then they shape the wax into the most beautiful and ingenious houses.

LESSON V.

CATERPILLARS, MOTHS, AND BUTTERFLIES.

The Rearing of Caterpillars.—When I was a school-boy I was taught by my companions to keep Caterpillars. Near our school-house was a large field, in one corner of which nettles grew plentifully, and here we used to capture our live-stock. The favourite Caterpillars were those of the Small Tortoiseshell Butterfly and the Tiger-moth, especially the latter, which we called Woolly Bears. We made paper cages, after a fashion known to all school-boys, and after feeding our Caterpillars for a month or two, were often rewarded by getting the handsome Butterfly or Moth, which comes out late in the summer. I must admit, however, that we often lost our Caterpillars, generally by some piece of carelessness, such as forgetting to feed them, or letting a heavy book drop on the light house of paper in which they dwelt. Nowadays, though the taste for rearing Caterpillars has not left me, I take more pains, and manage better. It is well to keep good-sized branches or stems of the food-plant, with plenty of leaves on them. To make them last long, the cut ends must be kept moist. There is nothing better than a flower-pot or pickle-bottle filled with wet sand. Stick the cut ends of the branches deep down into this, and the leaves will keep green for many days. If you have a room, which is not visited by meddlesome people, you hardly want anything more. Put your jars on a bare table, so that you can sweep it clean when you think fit. Now and then a Caterpillar will go astray, but it is found and put back without much difficulty. This plan does

not answer with Woolly Bears, which are active and fond of exploring. Most people who keep Caterpillars have not a room to themselves, and must imprison their pets. A large box with the top made of perforated zinc instead of wood, and with a pane of glass in front, is handy to keep the bottles in, and will prevent the Caterpillars from wandering. Some people put a bell-glass over each bottle instead, or merely tie a piece of muslin over the food-plant. You will find that a little contrivance will save much cost in fitting up a lodging for your Caterpillars.

The best Sorts to keep.—The next thing is to stock your house. June is the best time to begin, for then you can get plenty of leaves.

It will save trouble, while you are new to the business, to go to a dealer for eggs or young Caterpillars. There are several dealers in London who send them out by post to all parts of the country. I do not think that you can do better than ask for eggs of the Small Tortoiseshell Butterfly, the Tiger-moth, and the Vapourer-moth. The first two feed on the Nettle, but the Tiger-moth Caterpillar will also eat Dock-leaves or Lettuce. The Caterpillar of the Vapourer

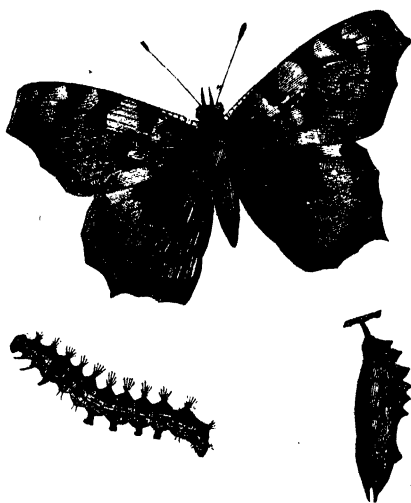


Fig. 45.—SMALL TORTOISESHELL BUTTERFLY, WITH LARVA AND PUPA.

moth is fond of Laburnum and Hawthorn and Rose-leaves; but it will eat the leaves of most of our common trees.

Hairs of Caterpillars.—All these Caterpillars are hairy. The back of the Woolly Bear (larva or caterpillar of



Fig. 46.—TIGER MOTH, WITH LARVA AND PUPA.

the Tiger-moth) is covered with long silky hairs as close as in a brush. The Vapourer-caterpillar has four thick pencils of light-coloured hairs on its back, besides several brushes of dark hairs, which look rather like horns. There is a pair of these on the sides of the head, another pair near the middle of the body, and a single brush at the tail. This Caterpillar is blotched with red, and is really a handsome creature. The larva of the Small Tortoiseshell

Butterfly is dusky and spotted, with stiff, branched hairs scattered over its body. What is the use of these hairs? First of all, they stick in the throat of any Bird which tries to swallow the Caterpillar. That is a great point. Birds soon learn to avoid them, and the lives of countless larvæ are spared. But the hairs have another use also. You will find that the Woolly Bear is very active, and runs about the branches. Now and then it gets a tumble, but as it falls it rolls itself up into a ball, and when it reaches the ground it picks itself up directly, and is none the worse. All Caterpillars which live at a height from the ground are liable to be shaken off, but those which are protected by elastic hairs, standing out like springs on all sides of their bodies, can fall from a good height without injury.

Legs and Jaws.—When you find one of these Caterpillars quite still, and with its side turned towards you, notice its feet. Behind the head are three pairs of long pointed feet, corresponding to the legs of the Moth or Butterfly. Farther back you will see four pairs of short, stumpy feet, which are found only in the Caterpillar. These support the hinder part of the body. At the tail are two more, which can be turned towards each other, like finger and thumb. These are particularly useful in grasping. Caterpillars can generally hold on to a twig by the last pair of feet only. The head is small, black, and shiny. It carries a pair of strong jaws, which are busy at work most of the day, for the Caterpillar eats much in order to grow fast. The head is also provided with a pair of short feelers, and other parts, which can only be seen by a magnifying glass. There are very small eyes on the top of the head.

Breathing-holes.—Look at the sides of any of these Caterpillars, and you will see the breathing holes. These are very plain in the Woolly Bear, because they are edged with white. There is a pair of openings to every ring of the body except two, the second and third behind the head. The air taken in by these holes is carried by branched tubes to all parts of the body. You remember that Insects do not take in air by their mouths, as we do, and they have no lungs to breathe with.

Feeding.—The Caterpillars feed greedily, and you will often have to bring them fresh leaves. Be very careful not to disturb them much when you change the food-plant. It is often best to leave the Caterpillar clinging to the old branch or leaf. It will walk away of its own accord after a time, and begin to feed on the fresh leaves.

Change of Skin.—Now and then Caterpillars turn sluggish, and cease to feed. They are about to moult, or change their skins. The old skin splits down the back, and the Caterpillar wriggles out with some difficulty. You see that the new skin is got ready before it is actually required, and at last nothing has to be done but to slip off the old skin. By changing its skin from time to time the Caterpillar can grow bigger without stretching the old skin more than it will bear. As soon as the larva has become free it proceeds to eat its cast-off skin. This is always done in a particular way. It turns round, until it is in a line with its old skin, head to head, and then eats it up from head to tail.

Change to a Chrysalis.—At last the Caterpillar has done feeding, and has grown to its full size. The next thing to be thought of is to lay the eggs, out of which a new set of Caterpillars is to be hatched. But it would not

do for the *Caterpillar* to lay eggs. They could only be laid on the very same plants upon which the *Caterpillar* lived. Before long those plants would be crowded with *Caterpillars*, or even eaten up altogether. The eggs must be carried far away, and laid in a fresh place. To make this possible the Insect must, as a rule, get wings. Now this is a serious business. A great change has to be made in the form and habits of the *Caterpillar* before it can be prepared to fly. The work is begun in good time. Long before the *Caterpillar* ceases to feed, wings and a new set of legs and new eyes, and other parts which will be afterwards wanted, begin to grow beneath its skin. In fact a new skin is formed within the old one, as in an ordinary moult, but this time the new skin is quite different from the old one in which it is enclosed. There is not much room for the new legs and wings under the old skin, and they are very much cramped and curled up. The old jaws will not suit the winged Insect, which cannot stop to eat green leaves and such things, but is fed upon the sweet juices of flowers. The old eyes will not do either. A flying Insect needs far keener and longer sight than a creeping *Caterpillar*. Accordingly the last moult of the *Caterpillar* is much more important and serious than any other. A time comes when the new parts have grown so big that they get in the way of the old ones. The new sucking organs of the mouth prevent the old jaws from working any longer. When this happens the *Caterpillar* stops feeding. But it is by no means ready to fly as yet. None of its new organs are fully formed. The wings are short, and quite unfit for flying. The legs are far too soft to bear the weight of the Insect. The new mouth-parts and the new eyes cannot be used for a long time. It is

plain that the Caterpillar must lie up and rest, for its old tools are spoilt and the new ones are not yet ready. So the Caterpillar changes into a Chrysalis, or Pupa, and rests for a time. The way in which it does this is very nearly the same in all our Caterpillars. I will first describe the change as it takes place in the Small Tortoiseshell.

Chrysalis of Small Tortoiseshell Butterfly.—When the Caterpillar is full-fed it begins to spin a very simple sort of web upon the nettle. Then it fixes the hooks of the last pair of feet into the web, and gradually straightens out its body, so as to hang head downwards.

At this time the Caterpillar is in a curious condition. It has the outward appearance of one of the Caterpillars which are still busy feeding, with strong jaws and short feelers, three pairs of pointed legs, four pairs of short feet, and a pair of claspers at the tail-end. But all these parts are mere skin; close under them are the parts of a Butterfly*—a long trunk or sucker, three pairs of long legs, two pairs of wings, and no legs at all in the hinder half of the body. No wonder that it needs to rest and collect itself when the inside of its body agrees so little with the outside.

The Caterpillar hangs head downwards, and before long loses the power of moving its legs. Then the skin splits once more, and is slipped upwards towards the web. The Chrysalis in this way gets free from the skin of the Caterpillar, which is generally dropped to the ground.

I must try to make you understand clearly that the Chrysalis has all the parts of the Butterfly, but that these parts are still soft and tender. When it first comes out

* Strictly speaking, these parts belong not to the Butterfly, but to the Pupa; the organs which will afterwards be used by the winged Insect are developed within them. But this distinction need not be attended to by very young naturalists.

from the Caterpillar-skin, its wings, and legs, and long antennæ, and sucking trunk, are to be seen quite plainly. They are enclosed in a tight-fitting skin, which will only be shed when the Butterfly comes out; but this skin is at first perfectly transparent. The Chrysalis now arranges all these parts in an orderly manner, different from that in which they were previously packed. The two pairs of wings are folded over the breast, one pair outside the

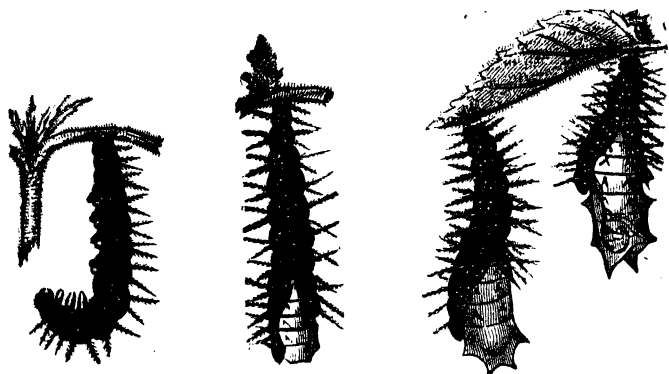


Fig. 47.—PEACOCK BUTTERFLY CASTING THE LARVAL SKIN.

other, in much the same way that a boy's jacket is buttoned across his chest; but you must suppose that the boy has two jackets on, to make the comparison complete. This leaves a three-cornered space beneath the head, which would be filled in the boy's case by a necktie. Here the Chrysalis arranges its six legs. In front of these it lays out its long antennæ, one on each side; while the sucking trunk is placed in the middle. A sort of gum then flows out from the body of the Chrysalis, which hardens after a time, and fastens the limbs in their place. The Chrysalis

looks more like a mummy than a Butterfly when all its limbs are glued down. The gum turns dark-coloured and horny as it dries, and then the Chrysalis moves no more, until it has gained enough strength to tear itself free from the mummy-case.

The Chrysalis of the Tortoiseshell Butterfly generally gets a gilded appearance after a few hours. I need hardly tell you that it is not gilded with gold-leaf. It is said that this colour is produced by the shining of a white skin through a coat of yellow varnish or gum.

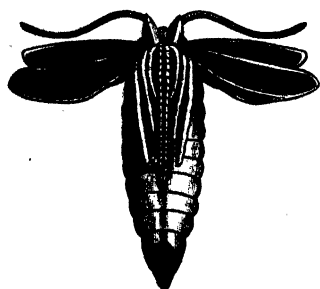


Fig. 48.—CHRYSALIS OF TORTOISE-SHELL BUTTERFLY, WITH WINGS AND ANTENNÆ SPREAD OUT.

There is nothing more to do for the Chrysalis but to let it rest undisturbed, hanging by its tail. In a few days or weeks it will burst its case, and a beautiful Butterfly will come out,

painted red and yellow and brown, with a row of blue spots along the edges of its wings.

Chrysalis of Tiger-moth.—The Tiger-moth Caterpillar makes a cocoon, or woven egg-shaped case, instead of a web, and weaves most of its own hair into it. When the Moth comes out you will be delighted with it, for it is one of our handsomest Insects. The fore wings and fore part of the body are black and white; the hind wings and hind part of the body are red and black.

Chrysalis of Vapourer-moth.—The Vapourer Caterpillar also spins a cocoon, and remains concealed in it until the Moth is ready to come out. The male Moth is brown,

with a white spot on each fore wing. The female has a great fat body, and no wings that you can see. You will find her clinging to the outside of her cocoon, and she lays her eggs there. If you look carefully you can see her breathing. She moves the hinder end of her body in and out like a concertina. Wasps and Bees can be seen to

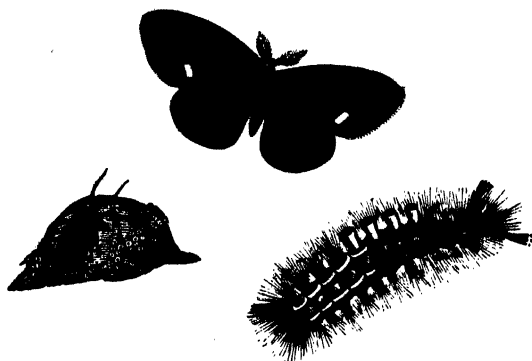


Fig. 49.—LARVA AND MALE AND FEMALE VAPOURER-MOTH.
The female is wingless.

breathe in the same way ; but I know of no other Moth or Butterfly which can be *seen* to breathe.

How the Female Vapourer-moth manages without Wings.—I told you that the Insect must, as a rule, have wings when it is ready to lay its eggs ; but you observe that the female Vapourer-moth has no wings fit to fly with. How does it manage to lay its eggs in fresh places, and avoid crowding ?

Most Insects which feed upon plants will eat one particular kind only. They will starve rather than eat any other. Such Insects are very liable to be overcrowded, especially if their food-plants grow singly, each by itself.

But if the Insect feeds upon *trees*, which produce great numbers of leaves, there is less risk of overcrowding; and if it will eat leaves of any kind, it will have no difficulty in getting supplied. The larva will seldom require to move to another tree; and if it does, the very next tree will do. Such larvæ run little risk of overcrowding.

The Vapourer larva is one of these. You will learn for yourselves, if you rear them, that they feed on the leaves of trees, and that they are not at all dainty about their food. I believe that this is the reason why the female can manage without wings.

LESSON VI.

ANIMALS OF ALL SORTS.

WANTED:—*Examples of any of the animals mentioned. A fresh Fish, with large Scales, such as a Herring or Gold Fish. Live Gold Fish. Black and white bowls.*

Classification.—There is such a vast number of different kinds of animals that we cannot remember the names of more than a very small part. The most learned naturalist does not know a tenth of all the animals to be met with in his own country, and when he sees a new animal he often does not know what to call it. But he knows what animals it most resembles. He can turn to his books, and make out with a little time and patience all that others have found out about it. He can do this because the facts have been classified, that is, arranged in an orderly manner.

It is not necessary for you to be able to name all the animals which you may see, but I think you would like to

know what *sort* of animals they are. Probably you would be satisfied for the present with knowing that they are Birds, Insects, Worms, or Corals. Afterwards you can learn more if you like.

Two Main Groups of Animals.—We divide animals into two large groups, Vertebrates and Invertebrates. Vertebrates have a skeleton inside their bodies, and a back-bone, which is nearly always jointed, and red blood. Invertebrates have no back-bone at all, and no red blood.* If they have a skeleton it is outside their bodies.

Classes of Vertebrates.—Vertebrates are divided into Mammals, Birds, Reptiles, Amphibians, and Fishes. The first three always breathe by lungs, the last two breathe by gills, at least when they are young.

When we have learnt so much we can go a step farther. Mammals are covered with hair, Birds with feathers, Reptiles with scales. Amphibians have feet like land-animals, if they have feet at all. Fishes have no feet, but fins instead.

Table of Vertebrates.—We can now make a table of Vertebrate Animals.

VERTEBRATES.—*Animals with a back-bone and red blood.*

Division I.—LUNG-BREATHERS.

Class i. *Mammals.* Covered with hair.

„ ii. *Birds.* Covered with feathers.

„ iii. *Reptiles.* Covered with scales.

Division II.—GILL-BREATHERS.

Class iv. *Amphibians.* Feet like those of Reptiles and Mammals. When full-grown they often lose their gills.

„ v. *Fishes.* No feet, but fins instead. •

* There are hardly any rules in Zoology without an exception. The Earthworm, though an Invertebrate, has red blood.

I think you would now be able to put almost any Vertebrate animal in its right class. It is not much to be able to do that. It is like knowing your A B C. The A B C is hardly of any use by itself, but we must know so much in order to be able to know more.

Mammals.—I have already described several different kinds of Vertebrate animals to you. Let us go over them again and take the Mammals first. The Cat and Dog are hunting or CARNIVOROUS Mammals. The Sheep, Cow, and Horse are grazing HOOFED Mammals. The Squirrel, Rabbit, Rat, Mouse, Vole, and Rabbit are GNAWING Mammals. The Shrews are INSECT-EATING Mammals. Besides these, there are many other kinds such as ELEPHANTS, WHALES, and BATS. Men are Mammals too, and belong to the same order as the Monkeys. We might call it the MAN AND MONKEY order.

Why do we call the Bat a Mammal, for it flies like a Bird? Because it is covered with hair instead of feathers, and the young ones are fed on the milk of the mother. I told you once before that this is a certain mark of all the Mammals. Besides, the wing of the Bat is really more like the paw of a Mammal than the wing of a Bird. It has a thumb and four long fingers, while the Bird's wing has only a thumb and two fingers, all very stunted and changed in shape.

Why do we call the Whale a Mammal, for it swims in the sea like a Fish? Because the young are fed on the milk of the mother. Whales do not breathe by gills like Fishes, but by lungs like Mammals. If they are Mammals they ought to have hair on their bodies. I must admit that a full-grown Greenland-whale has no hair, but it had bristles on its upper lip when it was younger,

and some other kind of Whales have a few hairs throughout life.

Birds.—What sorts of Birds do you know of? The Duck and the Goose and the Sea-gull have webbed feet for swimming.

The Herons, and Storks, and Cranes have a long neck and a long bill and long bare legs. They are well fitted for wading and fishing.

Hens and Pheasants and Grouse have short wings, and cannot fly very far. They have strong bills and strong toes, and many of them make their nests on the earth.

Doves have weaker bills and toes than Hens, and can fly much better.

Woodpeckers and Cuckoos and Parrots live much on trees, and have strong toes, some of which can be turned forwards and others backwards, so as to grasp a bough firmly.

The small Birds called **PERCHERS** include the Swallows, Crows, Warblers, Thrushes, Larks, and Finches. All our Song Birds belong to this division.

Eagles and Hawks and Owls have a sharp beak turned down at the point, and long hooked claws. They are called **BIRDS OF PREY**.

OSTRICHES have toes fit for running. They cannot fly, and their quills are turned into flexible plumes.

Do not try to remember all these kinds of Birds, but if you happen to see a Bird close at hand, look at its bill and toes, and try to make out by the book what sort of Bird it is.

Cold-blooded Vertebrates.—Mammals and Birds are very active, and this is probably the reason why they have hot blood. They breathe fast and work hard. Their

bodies require much heat to keep them in good health, and this heat is obtained from the food which they take into their bodies. Mammals and Birds keep the heat in their bodies as much as possible. You know how we keep in the heat of our bodies. By wrapping clothes or blankets round us. Most Mammals have a natural covering of hair which keeps them warm. The Whale is not covered with hair, but it has a thick covering of fat or blubber beneath



Fig. 50.—TORTOISE.

its skin, which answers the same purpose. The Bird is kept warm by its feathers. Reptiles and Amphibians and Fishes are not kept warm at all. Their blood is hardly warmer than the outer air, and they do not require a covering to keep the heat in, but only to protect their bodies from bites and scratches.

Reptiles.—Can you mention any Reptiles? Crocodiles, Tortoises, Snakes and Lizards. They are covered with scales. So are Fishes, but there is a difference between the scales of Reptiles and the scales of Fishes. If you scrape a Fish's skin, some loose scales will come out. But a

Reptile's scales are never loose. They are merely thicker parts of the outer skin. Fish-scales belong to the inner skin, and are covered by the thin outer skin. If you had a great coat which had patches of leather sewn upon the outside, that would be a little like the skin of a Reptile. But to get anything like the skin of a Fish you must suppose that the great coat had many inside pockets, each one with a

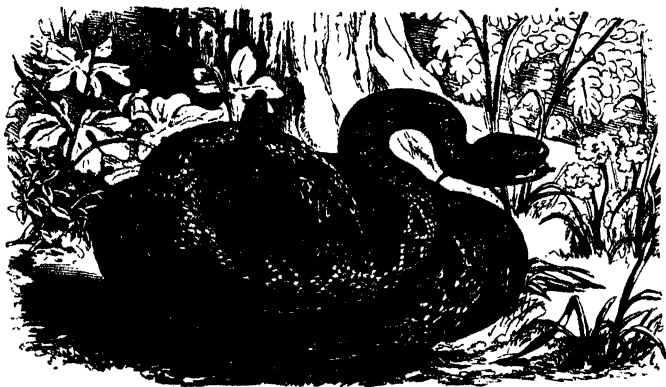


Fig. 51.—RATTLESNAKE.

piece of leather in it. Reptile-scales are sometimes called *false scales*. You can see them very well in the cast skin of a Snake. Do you know that Snakes shed their old skin now and then?

Amphibians.—What Amphibians do you know? The Frog, of course. The Frog is a leaping animal, and has no tail. Newts and Efts do not leap at all; they have long tails. We have, therefore, two sorts of Amphibians, Frogs and Toads, which leap, and secondly, tailed Amphibians, which do not leap. There are a few Amphibians which have no legs, and look very Snake-like. They have also

very small scales in the skin. These creatures were long reckoned among Reptiles, until it was discovered that they have gills when young. True Reptiles never have gills at all. We have none of these Snake-like Amphibians in Europe,



Fig. 52.—LIZARDS.

but they are common in Brazil and Ceylon. They live underground like great Earthworms, and come out at night.

The Frog.—The Frog has four legs, but no tail. The hind leg is very long, and the hind toes are joined together by a web, which is useful in swimming. The Frog can not only leap a long way, but it can also swim very well. It is a weak, defenceless creature, and can only escape the many enemies which are ready to devour it by escaping their notice, or suddenly leaping away from them. The Frog can change its colour, so as to look as like as possible

to the ground on which it lies. When a Frog is found on grass, it has a greenish colour like that of grass. In the bed of a clear gravel stream it turns yellow, and in the dark waters of a weedy pond it turns almost black. The



Fig. 53.—SNAKE-LIKE AMPHIBIAN OF CEYLON.

Frog changes colour slowly, for it does not often move to a ground of different colour. Quick-moving Fishes, like Trout or Gold-fish, change colour much faster, as we shall see before long.

Tadpoles.—When the Frog is quite young it is called a Tadpole. The Tadpole is quite different from the full-grown Frog. If you look out in March, you will see

plenty of Tadpoles in the ditches, and also the eggs from which Tadpoles will afterwards be hatched. Tadpoles are wriggling black things with long tails. The eggs are black too, but each egg is covered with a transparent covering nearly a quarter of an inch thick, which is made of the same substance as white of egg. The yolk looks black because it is coated on the outside with a layer of black stuff, like a sort of paint. If there were a shell outside the white, the egg would be like that of a very small Bird. The Frog's eggs are sticky, and cling together in great lumps which we call Frog-spawn. You can often see the lumps of Frog-spawn floating on water in spring. Toad's eggs do not form lumps, but long ropes. The Tadpole of the Toad is almost exactly like that of the Frog.

A Frog feeding.—It is very amusing to watch a Frog feeding. It feeds partly on Flies and small Insects,



54.—FROG'S TONGUE.

but does not despise Slugs and Snails and Worms. In summer I fancy that it feeds chiefly upon Flies. If many small Flies are about, the Frog sits quite gravely, and does not seem to move a muscle. Every now and then, if you watch carefully, you will see

a quivering movement of the head, and a Fly disappears down the Frog's throat. What the Frog does in swallowing is really this. He opens his big mouth as far as it

will go, flings out his long tongue, picks up the Fly, draws back his tongue, and shuts his mouth again. All that is done as quickly as you can wink. The tongue of the Frog is well suited to this mode of feeding. It is long and flat, like a strap, and is fastened to the front of the lower jaw. It lies loose in the mouth, and is ready to be flung out at any moment. If you want to see Flies picked up by a Frog, look out for a Frog seated among stones in the bed of a stream in summer. But you will not see much except that the Flies drop off one by one.

Fishes.—Most Fishes are covered with scales. The scales are held fast by a thin transparent skin, which you hardly see at first. If we scrape the skin with a knife some of the scales will be loosened, and then we shall see the pockets in which they lie. Notice that the scales overlap. Those in front overlap the scales next behind them.

Behind the head of the Fish are the gills, protected by a stiff flap, called the gill-cover. Raise the edge of the gill-cover, and you will see the red gills. They are red because much blood flows into them. Each gill has the form of a fine comb. Pass the

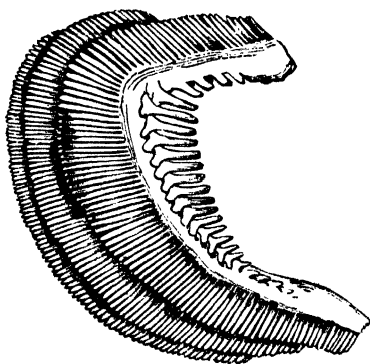


Fig. 55.—GILLS OF FISH.

handle of a penholder into the mouth of the Fish, and it will easily come out at the gills. A living Fish continually takes in water at the mouth, allows it to flow over the

gills, and then passes it out beneath the edge of the gill-cover. This stream of water bathes the delicate fringes of the gills, and purifies the blood which flows in them. Though the water continually streaming past purifies the blood, the water and the blood do not mix, or even touch one another. There is always a thin skin between.

Fishes which live in quick streams always like to keep their heads pointing up-stream. If you fish the stream,

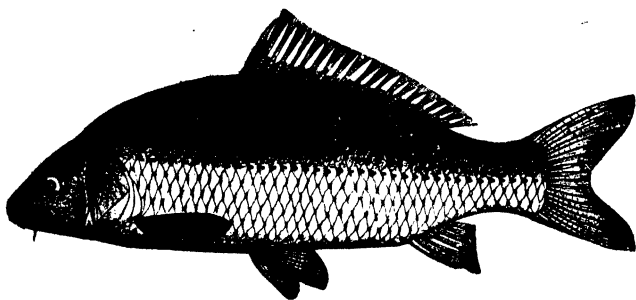


Fig. 56.—FINS OF FISH.

you must not walk *down* the bank in the same direction as the water flows. That would mean that the Fishes would all be looking towards you, and they would take fright before you could come near them. Why do the Fishes keep their noses up-stream? To prevent the rushing water from entering the gills from behind. It would stop the current which naturally passes backwards from the mouth, and would be apt to catch the gill-cover and wrench it.

Now look at the fins of the Fish. They are thin, and almost transparent, but stiffened by bony rays, which spread out like the spokes of a fan. When the Fish swims fast it uses the tail-fin, which is much more powerful

than the others. The paired fins are chiefly used for slight movements of the body. How many paired fins are there? Four—that is, two pairs.

Changes of Colour in Fishes.—Here are two live Goldfish in a bowl of white earthenware. I have chosen Fishes which are rather pale and mottled in colour, but you see that they are very nearly alike. I have on the table a second bowl which is painted black. Now I lift one of the Fishes out of the white bowl, and put it into the black one. In five minutes I return it to the white bowl, where the other Fish has remained all the time. You see that the two Fishes are now quite different in colour. The one which has been kept in the black bowl for a few minutes is decidedly darker than the other. The difference is becoming less marked, and in a few minutes more they will both be of one colour as they were at first. How is the change of colour brought about? There are specks of black and yellow colour in the Fish's skin, and when the Fish is placed upon the white ground, the black specks grow smaller and smaller, and the yellow specks larger and larger. If the Fish is placed on a black ground, the specks alter in the opposite way. The black specks enlarge and the yellow specks grow smaller. I do not think that the Fish or Frog intends to change its colour, or knows anything about it. If the Fish or Frog is blind, so that it cannot see the colour of the ground, its colours do not change.

Invertebrate Animals.—Invertebrate animals never have a back-bone, and hardly ever red blood. Some of them are altogether soft. Others have a hard shell on the outside of their bodies. They never have bones.

Let us think of some very common Invertebrate

animals. The Snail, the Insect, the Worm, are all Invertebrates. There are many other kinds which you are not so likely to know. •

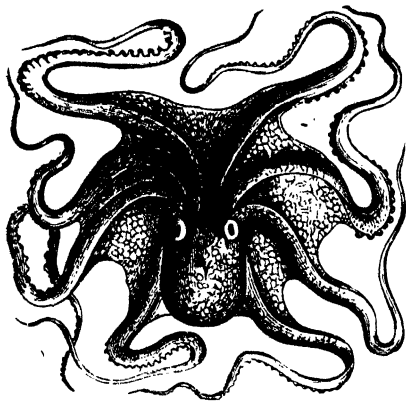


Fig. 57.—CUTTLE-FISH.

The Snail has a hard shell, but all the inside of its body is soft. The Insect has a hard skin divided into many rings, but all the inside of its body is soft. The Worm is altogether soft. None of these animals have any bones.

Now let us think of some other Invertebrates resembling the Snail, Insect, and Worm. Slugs are very like Snails, except that they have no shell. Crabs and Lobsters have a hard skin, divided into many rings like Insects, but they live in water, while the Insect generally lives on the land, or flies in the air. The Leech has a soft body like the Worm.

These three kinds of Invertebrate animals are pretty easy to distinguish. They are called by naturalists Molluscs, Arthropods, and Worms. *Mollusc* means *soft-bodied*; *Arthropod* means *jointed-leg*.

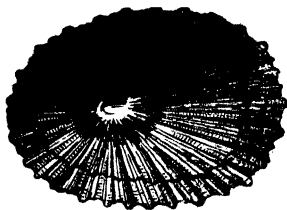


Fig. 58.—SHELL OF LIMPET.

Molluscs.—The Molluscs are very many, and some of

them look very different at first sight from the Snail. Cuttle-fish, Oysters, Mussels, and Cockles are all Molluscs. Some have no shell at all; some have a shell in one piece, shaped like a ram's horn, or a cap; some have a shell in two pieces, which are joined together by a hinge. Such shells as these last are called *bivalve*. The body is never jointed. Most Molluscs live in the sea; a few live in fresh water and a few on the land.

Arthropods.—Arthropods have a hard skin, and the body is ringed to make it capable of bending. The legs have also a hard skin, and are jointed to make them capable of bending. There are land-Arthropods which breathe air, and there are water-Arthropods which breathe by gills.

Worms.—Worms have soft bodies. Many of them have no legs. The body is ringed, but the rings are not nearly so stiff and firm as those of an Arthropod.

Table of Invertebrates.—Now let us make a table of some of the chief Invertebrate animals.

INVERTEBRATES.—*Animals without back-bone.*

MOLLUSCS.—Body not jointed. Often a hard shell.

Cuttle-fish.

Snails and Slugs.

Bivalves.

ARTHROPODS.—Body and legs jointed. A hard skin.

Air-Breathers.

Insects.—(3 pairs of legs; body divided into 3 regions—head, thorax, and abdomen; often winged).

Spiders.—(4 pairs of legs; body divided into 2 regions—the head and thorax being joined; never winged).

Centipedes.—(Many pairs of legs; a separate head, but no other distinct regions; never winged).

Water-breathers.

Crustaceans.—(Number of legs and arrangement of regions various).

WORMS.—Body ringed, without limbs, or with very simple limbs, which are not jointed.

There are many other kinds of Invertebrate animals which I have not mentioned at all as yet. Some of these are given in the table below.

Table of the Animal Kingdom.

VERTEBRATES.

MAMMALS.
BIRDS.
REPTILES.
AMPHIBIANS.
FISHES.

INVERTEBRATES.

MOLLUSCS.
Cuttle-fishes.
Snails and Slugs.
Bivalves.

ARTHROPODS.
Insects.
Spiders.
Centipedes.
Crustaceans.

WORMS.

STAR-FISHES.

ANEMONES, JELLY-FISHES, CORALS.

SPONGES.

MICROSCOPIC ANIMALS, of very simple structure.

LESSON VII.

EGGS AND CHICKENS.

WANTED :—*Several Fowl's Eggs, boiled and unboiled.*
Eggs which have been sat upon two or four days.
Saucers, Saline Solution, Scissors.

Shape of Egg.—Here is an object which all of you know very well. It is nothing but a Fowl's egg. Of what shape is it? Someone says, "Nearly round." That

does not give a very good notion of the shape. We use the word *round* in two senses. We call a penny *round*, and we also call a cricket ball *round*. These two quite different shapes have to be distinguished. The penny is *circular* and the ball is *spherical*. Even now there is a possibility of confounding two different shapes under the name circular. A ring is circular as well as a penny. If there is any chance of mistake, we may use the word *annular* to signify *ring-shaped*.

If we say that the Fowl's egg is nearly spherical, we shall have a rough idea of its shape. Let us measure the egg with a tape. I find that this egg is $2\frac{1}{4}$ inches long and $1\frac{3}{4}$ inches wide. It is 6 inches round, if we measure along its greater length, or major axis, and $5\frac{1}{4}$ inches round along its greatest width, or minor axis. Other eggs would not show exactly the same

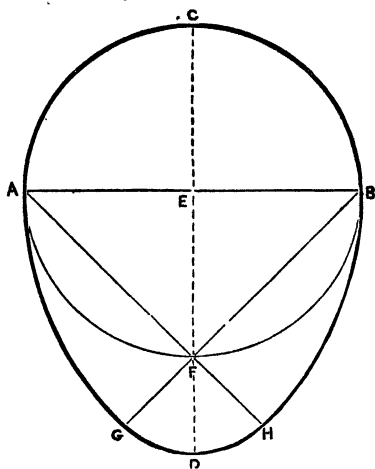


Fig. 59.—HOW TO CONSTRUCT AN OVAL.

measurements as the one which I have happened to take. Now let us draw our egg on the blackboard. We must make it larger than nature so that you can all see it. First, I will measure out a line 18 inches long (CD); that will be exactly 8 times the major axis of our egg. Then I measure off 14 inches (CF), beginning at one end of the major axis. Fourteen inches is 8 times $1\frac{3}{4}$ inches, and that is to be the length of our minor axis. I divide this

length of 14 inches into two equal parts, and mark the centre *E*. Now I take the compasses, fix one leg at *E*, and making *EC* the radius, describe a circle *AFBC*. Through *E* I draw a straight line *AB* at right angles to *CF*. This will be the minor axis of our egg; it is exactly the length of *CF*, that is 14 inches. Now we join *AF* and *BF*, and continue them forwards in the same direction as far as we please. Next I put one leg of the compasses on *A*, making *AB* the radius, and describe part of a new and rather larger circle outside the circle *AFBC*. The same thing is repeated on the other side of the axis *CD*, making *B* the centre, and *BA* the radius. Last of all, I finish the small end of the egg by taking *F* as the centre, and *FG* as the radius.

The figure which we have drawn is not an exact outline of a Fowl's egg, but it comes pretty near to it, and, as we saw, the two chief measurements are just in the right proportion. Our figure is made up of bits of four circles, a small circle for the small end, a rather larger circle for the broad end, and bits of two still larger circles for the sides.

We have now a tolerable representation of the egg on the blackboard. This figure is called an *oval* or *egg-shape*. It is sometimes used by architects for the outline of an arch.

Why of this shape?—Can you give any reason why a Fowl's egg should be of this particular shape? It is plain that a cube or any other shape with angles would not do for the Hen to sit upon. Besides the inconvenience to the Hen, such shapes would not be strong enough, and they would not roll. The Hen, as we shall see, turns her eggs frequently, and some

kind of rounded shape is necessary. Would a sphere do? Only pretty well. A spherical egg would roll too far, and in a straight line. If the egg were lying on sloping ground, and got pushed, it might roll a long way. Watch this spherical ball as it rolls on the table, how straight and far it travels with a slight push. But when I give a push to the egg, it curves round, and never gets very far from its starting point. One advantage of the oval form is, that it *will not roll in a straight line when it is pushed*, and thus it never rolls far away. There is another advantage in the shape of the Hen's egg. It is very strong, and will bear a good weight. If you hold an egg in your hand, and press as hard as you please *at the two ends*, you will not break it.

Egg-shell.—The egg-shell is made of chalk. It is hard, but very brittle, that is, it can easily be broken. It is full of pores or fine holes, which allow air to pass through quite easily. Things which are full of pores are said to be *porous*. You cannot see the pores of the egg-shell, because they are so small. What is the use of the pores? We shall see by-and-by that the chick breathes through them. If the egg-shell is varnished before hatching, the chick soon dies. If the shell is partly varnished the chick is generally deformed.

Contents of Egg.—What is to be found inside a Fowl's egg? White and yolk. Which of these is outside the other? The white. Is there anything else inside an egg? No doubt, when eating an egg for breakfast, you have now and then seen a tough skin next to the egg-shell, and outside the white. This is called the *shell-membrane*. At the broad end of the egg the shell-membrane

is double. There is an inner membrane and an outer membrane, and an *air-chamber* between the two. With a little care we shall be able to see this air-chamber for ourselves. I begin by tapping the broad end of the egg with the back of my penknife, until the egg-shell is cracked all over the end. Then I cautiously remove the shell bit by bit with this pair of nippers or forceps. Now you see the shell-membrane quite plain. When I have got a good piece of shell off, I take a pair of small scissors and cut through the shell-membrane at one place, just in the centre of the broad end of the egg. Nothing comes out. I have merely cut into the air-chamber, and there is still an inner shell-membrane, which prevents the white and yolk from pouring out.

Egg cut in two.—I will now cut an egg in two so as to let you see what there is inside. Of course I must take a hard-boiled egg, or else all the contents will flow out. I remove the egg-shell, bit by bit, along a line running from the broad to the narrow end, and then turn the egg over, and do the same on the under side. When a strip of egg-shell has been removed all round, I take a dinner knife, and make a clean cut through the whole egg. Now we see the white surrounding the yolk. The yolk is near the centre. Of what shape is the yolk? It is *spherical*, and appears circular when cut across. It is not quite in the centre, but rather nearer to one side than to the other. Outside the white comes the shell-membrane, and outside this is the shell. Here is the air-chamber at the broad end of the egg. I will draw what we have seen on the black-board. The drawing represents a *longitudinal section* of an egg, that is, a cut *along the length* of the egg.

White of Egg.—Now observe that the white of the

egg is not perfectly mixed up together. Here is a second hard-boiled egg, from which part of the white has been scraped off. With the back of a knife I can strip off a layer of white, bit by bit, and leave everywhere a perfectly smooth natural surface. If the white were not so brittle when boiled, I could unwind it like a ribbon. As it is, it breaks off, bit by bit, when I try to unwind it.

Yolk.—Towards the centre of the egg lies the yolk. It is a golden-red fluid enclosed in a delicate, transparent bag.

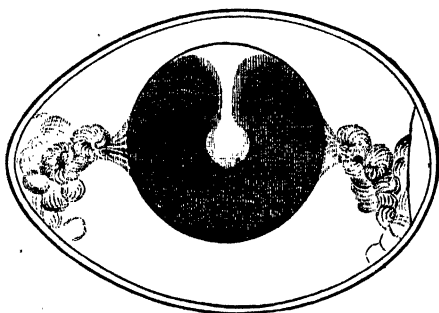


Fig. 60.—LONGITUDINAL SECTION OF FOWL'S EGG.

How do we know that it is enclosed in a bag? It is only necessary to break a raw egg into a saucer to answer the question. If the egg is broken carefully, the yolk flattens out, but remains together as a soft circular cake surrounded by the transparent white. But touch the yolk with the point of a knife, and the bag is burst. The yolk no longer keeps its regular shape, but spreads out in a blotchy mess.

While the egg is uninjured, and unboiled, one particular side of the yolk always floats uppermost. The yolk is spherical, and on one side of the sphere there is a patch of pale yolk, which is lighter than the rest, and always comes uppermost, however you turn the egg about.

Tangled cords in the white.—Fresh eggs broken into a saucer show two twisted and tangled masses of white, a little firmer than the rest, fastened at opposite sides of the yolk-bag. These are made of the same substance as the white; they are so transparent, and so like the rest of the white that it is not always easy to see them, but they are always there, and in many eggs they are quite plain.

What is the use of the pale patch in the yolk, and what is the use of the tangled cords attached to the yolk-bag? We may be quite sure that these things have some explanation, and a little patience will probably enable us to find out what it is.

Where the Chick forms.—I must first tell you that the young chick begins to form on the surface of the yolk, just within the thin bag which we found. It always lies exactly over the patch of pale yolk. This is a great advantage to the Chick. Its body lies on that side of the egg which is turned towards the warm body of the mother, and away from the cold ground. The Hen turns the eggs with her feet, once or twice a day, and when she does so, the Chick turns gently round, and gets back to its old place on the top of the yolk-bag. The yolk-bag, we might say, is buoyed up on one side, so that it always recovers its original position, no matter how often it turns. But it must do so very gently and steadily. If the yolk-bag spun round quickly, whenever the egg chanced to roll fast, the tender body of the little Chick might be injured by rubbing too hard against the white. The twisted cords prevent this. They are made fast to the yolk-bag, and they are entangled in the white, so that they check any quick spinning round of the yolk, and cause yolk and white to turn round together at a very gentle rate.

Why Hens turn their Eggs.—One question, you see, leads to another. We have next to ask why the Hen turns her eggs at all. The Hen, I need hardly say, knows nothing of the reason, and could tell us nothing even if she could speak; but there is a very good reason for what she does. Eggs have been hatched without turning, on purpose to find out whether turning makes any difference. The eggs used in the experiment were not set under a Hen, but in a drawer or box kept warm by hot water. It was soon found that most of the Chicks died early when the eggs were not turned, and those which lived were strangely deformed. The limbs and the body of the growing Chick touch the shell-membrane, or the temporary breathing organ, which will be described by-and-by, or some other things inside the egg which are not part of the Chick. Whenever the Chick lies for a long time touching any such things without changing its position, it grows fast to them, and so becomes distorted and perhaps unable ever to leave the egg-shell without fatal injury. But when it is moved every few hours the chick keeps free of surrounding objects, and its body is formed naturally.

Hatching without Hens.—I told you just now that eggs can be hatched without sitting Hens. In Egypt they are often hatched in ovens. A long low house is built, into which a man can just manage to walk or creep. Shelves are made on the inside of the walls, one above another, to hold the eggs. Wood fires are lighted on the floor, and kept constantly burning, and there are holes in the roof to let the smoke out. Great pains are taken to keep up a gentle and steady heat. All the people from the country round bring eggs to be hatched, and there is a

very simple way of paying the man who keeps the oven. Every one who brings two eggs gets one Chick in return. This way of hatching eggs artificially has been practised for thousands of years, and it is quite successful. In Europe eggs which are to be artificially hatched are generally kept in a drawer, under a large cistern of water, which is warmed by a gas-burner or oil-lamp. Not only can eggs be hatched in this way, but the young Chickens can be kept warm and comfortable until they are quite big and strong.

Hatching with Hens.—It takes just three weeks to hatch an egg. A suitable degree of warmth is necessary, as we have seen. Care must be taken not to dry the eggs. They do best when lying on the damp earth. If they are hatched in an oven or a drawer, water must be sprinkled about from time to time. Of course the eggs must be turned once or twice a day. There is another thing to be borne in mind. The Chicks will not thrive unless the eggs in which they lie are cooled twice a day or so. A sitting Hen leaves her eggs about twice a day, when she goes away to feed. During this time the eggs cool down a little. It seems that cooling in this way has become necessary to the Chicks, and they do not manage well without it. I cannot tell you why, but Chicks which have not been cooled once or twice a day are seldom born alive.

PRACTICAL INSTRUCTIONS FOR EXAMINING A CHICK FRESH FROM THE EGG. (*For the Teacher's Use.*)

Eggs partly hatched may often be obtained from a farmyard where Hens are sitting, or from an artificial incubator. Those which have been sat upon about two days and four days respectively are best suited for examination in the first case. They must

be marked when they are put under the Hen, to prevent mistake as to their age. January to May are the best months for hatching; at other times many of the eggs are not fertile, and produce no Chicks.

Examine the egg, if possible, while still warm. Have ready a saucer of saline solution (75 per cent. of common salt), warmed to the temperature of the hand, or a little beyond. Bore very carefully a small hole in the broad end of the egg, and cut away the shell, so as to open out the air-chamber completely. Observe the inner shell-membrane, which is now concave. Examine the yolk through the semi-transparent membrane, and watch its position while the egg is slowly rotated about its principal axis, which must be kept horizontal. The yolk always floats uppermost, and does not rotate. Then puncture the side of the egg near the middle of its length. After the shell-membrane is pierced, so that the pressure of the air can act upon its contents, these subside, and the shell-membrane at the broad end of the egg suddenly becomes convex. By opening the shell in this way, the yolk-sac and embryo are made to descend a little from the top of the egg, and are much less liable to injury than if the shell were opened without precaution. Cut round the egg-shell with strong scissors in a vertical plane, the principal axis being still kept horizontal. The egg must be slowly rotated, so as to bring the part under the scissors always to the top. When the halves are ready to part, lower the egg into the saline solution, break it open, and float out the contents.

After examination, the embryo may be cut out with a fine pair of scissors, floated into a small saucer, and preserved in weak alcohol, which should be replaced by strong alcohol next day. It will turn opaque, and some parts will be seen better than at first. The Chick can then be kept any length of time in a small bottle.

Chick after two Days' hatching.—If we take a Fowl's egg which has been sat upon [about forty-eight hours, we shall find the little Chick on the surface of the yolk, just within the transparent yolk-bag. It lies at

first face downwards upon the yolk. The body is surrounded by a transparent covering, the *amnion*, which is filled with a watery fluid. Outside the body is a circular patch covered with fine red blood-vessels. These blood-vessels are engaged in carrying particles of yolk to the body of the Chick. As yet the Chick has no mouth, and it is fed entirely upon yolk brought to it by the blood-vessels. We can see the heart beating

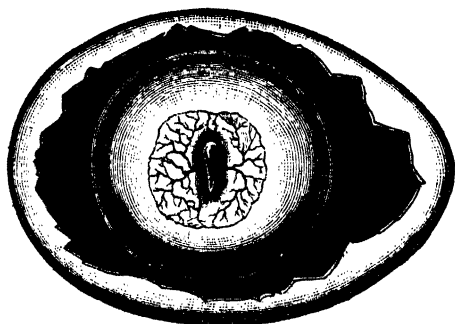


Fig. 61.—EGG WHICH HAS BEEN SAT UPON ABOUT FORTY-EIGHT HOURS.
The chick is seen on the top of the yolk-bag, which is partly overspread with blood-vessels.

away as busily as possible. We can also see the eyes, which are large and dark-coloured. Along the middle of the body, where the backbone will afterwards be formed, there is a double row of whitish dots, which can hardly be seen without a magnifying glass. The head is large, and bent round almost into the shape of a horse-shoe. Without a microscope it is hard to see more than this.

Chick of the fifth Day.—On the fifth day of hatching the Chick is found to have grown a good deal. It no longer lies face downwards, but on its side. Everything

is much bigger than it was on the third day. The wings and legs can now be seen as little clubs, standing out from the sides of the body. Besides the yolk-bag, a large bag filled with clear fluid is seen to hang from the middle of the body. This is called the *allantois*. It is covered with blood-vessels, and serves for the Chick to breathe by. From this time onward the allantois grows very fast, and spreads all round the inside of the egg-shell,

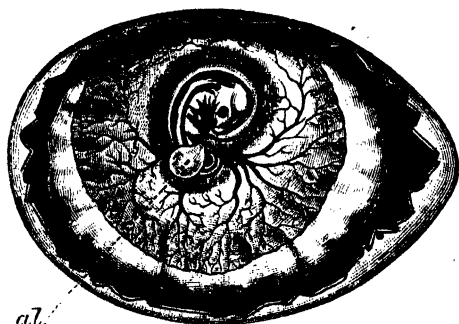


Fig. 62.—CHICK OF THE FIFTH DAY (*al*, *Allantois*).

covering the Chick in a kind of great hood. Air passes through the porous egg-shell, and is taken up by the blood-vessels of the allantois, and so carried to the Chick. The Chick never breathes air by its lungs until it is almost ready to escape from the egg.

What becomes of the White and Yolk.—All this time the Chick has been feeding upon the yolk, which is brought to it continually by the blood-vessels. Strange to say, the yolk gets no smaller, but even larger for the first few days. But the white of the egg wastes fast, and after five or six days there is much less than there was at first. It looks as if the white goes to

supply the yolk, while the yolk goes to supply the Chick. After a time all the white is gone, and then the yolk begins to waste and soon disappears altogether. The space which was at first taken up by the white and yolk is now filled by the Chick and its large breathing hood, the allantois.

Chick after the fifth Day.—I will now tell you what happens after the fifth day. On the sixth day the Chick may sometimes be seen to move a little when the egg is opened. On the ninth or tenth day feathers begin to appear. On the fourteenth day it is nearly as long

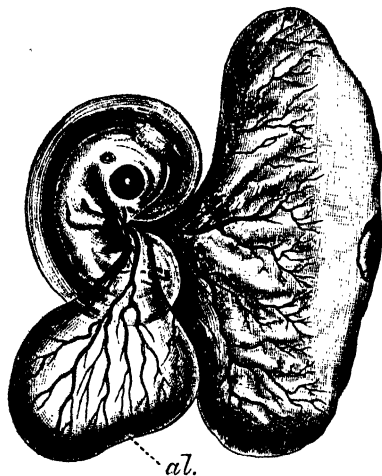


Fig. 63.—CHICK OF THE SEVENTH DAY
(*al.*, Allantois).

as the egg in which it lies. Soon after this it has to curl itself up, because there is hardly room enough for it inside the egg-shell. It always lies with its head close to the broad end of the egg. About the twentieth day the Chick grows restless, and begins to tap the shell with its beak. It tears open the air-chamber at the broad

now for the first time breathes air by the mouth. After this it pecks harder and harder, and at last it makes a hole in the shell; then it enlarges this hole, bit by bit, until it is able to creep out, and see for itself what the world is like.

The Chicks are generally very much tired by their struggles to escape, and some are so weak that they never get out, but perish before they have managed to free themselves. A strong healthy Chick soon recovers, and begins to run about, and pick up worms or grain. When it is cold or frightened, it runs to shelter itself under the feathers of the Hen. I dare say you have all seen a Hen walking about in the farmyard, with her brood of chickens following her and taking refuge at the least alarm under her wings.

LESSON VIII.

TADPOLES.

WANTED :—*Frog-spawn. Young Tadpoles.*

Frog-spawn.—Do you remember what I told you about Frog-spawn? It is a mass of black eggs, each surrounded by a transparent jelly. In Frog-spawn the eggs form irregular lumps; in Toad-spawn they form ropes, many yards long. Why are the eggs coated with jelly?

Use of the Jelly.—Eggs are good to eat, and eggs floating on the top of the water * would be soon picked up by Birds or Fishes or Insects, if they were not protected. The jelly is an excellent protection. Try to pick up one of the eggs with this pair of forceps. You cannot do it, however long you try. The egg slips away as the forceps close upon it. If a Bird tried to pick up the egg with its bill,

* Frog-spawn is often found floating. It is a little denser than water, and sinks to the bottom at first, but after a time it is usually buoyed up by bubbles of air.

or an Insect with its jaws, or a Fish with its mouth, it would be just the same. Ducks with their broad bills are almost the only animals which can eat Frog-spawn, and they find it no easy matter.

The jelly serves another useful purpose. If a number of black eggs were dropped into the water close together, they would lie one upon another. The outer ones would keep off the fresh water from those within. If this were the case, the inner eggs would hatch later, or not at all. The jelly *spaces* the eggs, so that each gets its fair share of air from the water.

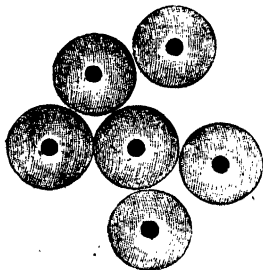


Fig. 64.—Frog's Eggs.

What happens if the jelly is removed from a number of Frogs' eggs? The experiment has been tried. Eggs have had the jelly cut and brushed away as carefully as possible, and they have been

left to hatch. But they soon perished. Small plants called "water-moulds," which abound in stagnant water, settled on the eggs, and lived upon them, and before long the eggs turned mouldy and perished. But the water-moulds cannot touch the jelly, which never turns mouldy or putrid.

We see that the clear jelly protects the Frog-spawn from being eaten, from being overcrowded, and from being over-run with moulds.

Why Frogs' Eggs are black.—The eggs themselves are black. They are only black on the outside, and even on the outside there is a small white spot. Where that spot appears the outer black dye is not present, and the white yolk shows. Why are the eggs black? It is, I believe,

that they may absorb as much heat as possible. White bodies reflect much heat. Black bodies reflect hardly any.

Now let us stop a moment, and consider what we mean by *absorbing* and *reflecting* heat and light. To *absorb* is to *drink in*, to *reflect* is to *shoot off*. Black objects absorb heat and light; white objects reflect them. If you had a wall opposite the window of your room and very near, you would find that it made a great difference whether the wall were white or dark-coloured. If the wall were white, it would reflect much light into the room; if it were dark it would absorb much light, and reflect little. A piece of white cloth reflects much light and heat, and does not get warm in the sun. A piece of black cloth absorbs much light and heat, and soon gets warm in the sun. When two pieces of cloth, one white and the other black, are laid upon snow in the sun, the black piece begins to sink after a time, but the white piece will hardly sink at all, however long the sun shines upon it. The white cloth reflects nearly all the heat and light which it receives. The black cloth absorbs nearly all the heat and light, and grows warm. If you understand what has been said you will be able to answer the question which follows. Why do people in hot countries wear white linen as much as possible, especially on their heads?

But we have forgotten our Frog-spawn. Why are the eggs blackened on the outside? In order that they may absorb as much heat as possible. Heat hastens the hatching-out of the eggs. If you put a batch of Frogs' eggs into a cold dark cellar they will take many weeks to hatch, but in a warm bright room they will hatch quickly. It is important for the eggs to catch all the heat they can from the feeble sunshine of March and April.

Do the sun's rays produce any other effect besides that of warming the eggs? The question may be answered by means of a very simple experiment. If we place two glass beakers containing Frog-spawn side by side, keeping them equally warm, but completely screening one of them by an extinguisher of brown paper, it will be found that both parcels of spawn will hatch out as nearly as possible together. This shows us that it is the *heating power* of the sun's rays which is of importance.

Shape of Frogs' Eggs.—Of what shape are the Frogs' eggs? Round. Do you mean round like a penny? No. I see you have forgotten what we have said about the different kinds of roundness. Is the Frog's egg round like a penny, or round like a ball? Round like a ball. We call that shape *spherical*.

Change in the Egg.—When the eggs have been hatching for two or three days you will see that they are no longer spherical. They become drawn out, and longer one way than the other. The head and tail and back are now forming. By-and-by the creature is found to have a round head and a flattish tail. In the middle of its body is a swelling. There the yolk lies enclosed in the body of the Tadpole. When the Tadpole has got so far, it wriggles out from the jelly in which it lay up to this time, and becomes free.

Hatching of Tadpoles.—You will find it an amusing occupation to watch Tadpoles grow. Tie a tin cup to the end of a long stick, and fish up some Frog-spawn from a pond or ditch. March is generally the best time of the year. Bring the spawn home, and put it in a pie-dish, and pour water on it, and keep it in a window till the Tadpoles hatch out. If you want to keep them alive after

that you must feed them with the fine green threads which make a sort of scum on the top of stagnant water.

Fresh-hatched Tadpoles.—When the Tadpole is first hatched it is a rather comical object. It is of a sooty

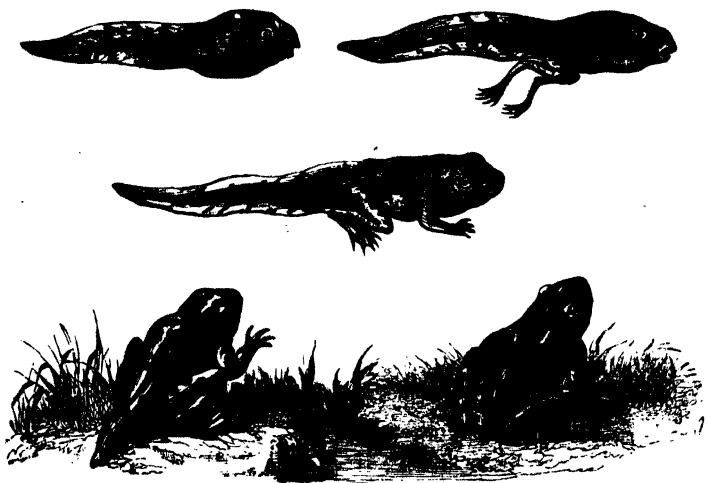


Fig. 65.—TADPOLES IN VARIOUS STAGES OF DEVELOPMENT.

black colour; it has no legs, and its tail is rather short. The sides of the body seem stretched over the rounded mass of yolk. At this time the Tadpole has no mouth.* Indeed, it has no use for a mouth, for it feeds entirely on

* Strictly speaking, there is a mouth which is blind—that is, it does not lead into the stomach.

the yolk inside its body. On the under side of the head are a pair of suckers, by means of which it clings to water-weeds, or to the side of the vessel in which it is placed.

Tadpoles with Gills.—After a few days the mouth appears. It has a pair of horny jaws, with which the Tadpole crops the plants upon which it feeds. Branched gills, which have a feathery appearance, now spring from the sides of the neck. Between the gills are slits leading into the mouth, and a stream of water flows out through the mouth over the gills. After two or three weeks a fold of skin grows over the gills, and they are no longer visible. At the same time the gills shrink. New gills, which are not seen from the outside, form on the edges of the slits. The tail is by this time broad and strong.

Legs appear.—Then the hind legs begin to appear as little projections at the root of the tail. They grow fast, and about two months after hatching the toes can be seen. The fore legs are at first hidden beneath the fold of skin which covers the gills, and they have to burst through this before they can show themselves.

Tail shrinks.—As the legs get longer, the tail shrinks. It is not cast off, as some people believe, but gradually gets smaller and smaller, until only a stump is left. The Tadpole now comes up to the top of the water from time to time to breathe. It has lungs, and is beginning to use them, but it still breathes by gills also. It does not care much for the small green threads on which it used to feed so greedily. It has now got the tastes of a Frog, and wants to feed on Flies and other small animals. It is almost impossible to keep your little Frog alive much longer, for you cannot feed it on the Flies which it

requires. To give it a last chance, you may take it out of the water and set it down in a ditch. Perhaps it may manage to live; but I believe that ninety-nine Tadpoles out of a hundred die before the end of the first summer. Many are eaten up by the larvæ of the Dragon Fly and other water Insects; many are gobbled up by Birds as soon as they take to the land; many starve; and many are dried up before they can find a good place to live in. No doubt it is because the young Frog runs so many risks that the female lays so many eggs.

Why Tadpoles change from Water to Land.—The Tadpole begins life as a creature very like a Fish, living entirely in the water, and breathing by gills. It ends as a Frog, living most of the year on dry land, and breathing air by lungs. Why should it change its mode of life in this singular way? I have put a rather hard question.

Why they cannot always live on Land.—Why should not the Frog live on land all the time? Because at first it has no legs, and no skeleton. It is very small and weak, and could not move on land, or save itself from drying up altogether. But why should it be so small and weak? Because it has been provided with only a very small stock of yolk. All the parts of its body which are formed down to the time that its mouth opens, have to be formed out of one little sphere of yolk. Why should the yolk be so very small? Why should it not be as big as the yolk of a Fowl's egg? Because the female Frog is only small herself, and she has to produce many eggs. She would have to be as big as a Horse to produce hundreds of large eggs. Why must the Frog produce so many eggs? Because the young run many risks, and a great many perish for one that survives. What a string

of questions! You see that there are a great many things to think of in the life of a Frog, many things that we should never have thought of for ourselves. I could make you a set of "whys" like "The House that Jack built," out of the history of the Frog.

Young Frogs run many risks. *That is why*

There must be many Tadpoles. *That is why*

The Frog must lay many eggs. *That is why*

The eggs must be small. *That is why*

The little Tadpoles must be small and weak. *That is why*

They cannot live on dry land. *That is why*

They must be born with gills, and live in water.

Why they cannot always live in Water.—But why should not the Frog live in the water all the time? Because it inhabits small fresh-water ditches and pools, which would soon get overstocked, and there would be hardly any chance of getting into other pools, unless they could manage to cross the land. Besides, ditches and little ponds are apt to dry up in summer, and what would become of the Frogs then, if they could not live in air? There are some countries which have plenty of great lakes and large rivers, in which creatures like big Tadpoles can find plenty of room, and need never be afraid of the water drying up. In some such countries there are Tadpoles as long as your arm, which never turn to Frogs. But Tadpoles which live in ditches must change to Frogs; and Frogs, which have many enemies, must be born as Tadpoles.

LESSON IX.

DOMESTIC ANIMALS AND CULTIVATED PLANTS.

Domestic Animals.—There are some animals which we call *domestic*, because they are kept and fed by Man, as if they were members of his household, or servants in his fields.

Uses.—Some of these are only valued for food, like the Pig; some yield clothing as well as meat, like the Sheep; some are used for drawing loads, like the Horse, Ass, and Ox; some, like the Cat, keep his house free of small thieves.

Two Ways in which Animals become Domestic.—Some domestic animals are merely tamed. They have grown quiet, but they have hardly any affection for their masters. The Ox and Sheep are animals of this sort.

Others have attached themselves to man. They live in his house as companions, and go out with him wherever he goes. The Dog is the best example; but some other animals have been known to do the same thing.

Different Domestic Animals named.—What domesticated Mammals can we think of?—Dog, Horse, Ass, Sheep, Ox, Goat, Cat, Rabbit, Camel. What domesticated Birds?—Fowl, Goose, Duck, Pigeon, Canary. In old times Falcons were tamed, and trained to hunt. Gold Fish and Carp might be called domesticated Fishes; but we can do little with a Fish, except feed it, and keep it for show. Do you know of any domesticated Insects? You cannot think of any? What! have you forgotten the Bee, which makes honey and wax for us; and the Silkworm, which makes silk? In some warm countries people take

great care of the Cochineal Insect, which yields a valuable dye. The House-fly lives in our houses, but we do not find it at all useful.

There are many creatures like Rats, Mice, and the House-fly, which we have not tamed and do not care

about, but which are nevertheless dependent upon Man. They can hardly manage to live except in our houses or barns, but they live with us rather as thieves than as helpers.



Fig. 66.—PEREGRINE FALCON.

Changed from their natural shape and colour. Most domestic animals become altered by captivity. In the wild state animals of the same species are almost exactly alike in

form, size, and colour, but when they are tamed by Man they often become very varied. What a number of breeds of Rabbits and Pigeons we have! But they are all descended from wild Rabbits or wild Pigeons, which are very much alike. When we make a pet of an animal, we try to keep the pretty sorts, and destroy the ugly ones, and thus it soon becomes varied. But where nobody takes

any pains to pick out his favourite shape or colour, the original shape and colour hardly change. The Ass and the Goose hardly vary in their colours, because no one has taken pains to save those which are a little different from common.

Effect of Selection.—It is possible to strengthen any slight peculiarity in a domestic animal, by keeping those which show more of it than others, and destroying those that show less. Men value a clever Dog, and when they find one they take care of it. But if a Dog is dull and stupid it is soon got rid of. In a long course of years the intelligence of Dogs has been raised by continual selection of the clever ones.

Nobody cares about the intelligence of a Goose, but only about its size and flavour. So our Geese do not grow clever, but they get heavier, and fatten sooner.

History of the Dog.—I fancy that the Dog first came about men's houses as a thief, to see what he could pick up. Whenever a man saw the Dog, he would throw a stone at him, and the Dog would run away howling. But the man would mind the Dog less after he got a little used to him, and would let him hide in corners, and pick up bones. All the Dogs of the village would make a troop, and live in the streets, as they still do in Eastern countries. When the man went out to hunt, the Dog would want to go too, and would yelp for joy. Perhaps the man thought that even a Dog's company was better than none, and let him follow. In time the man would find that the Dog could be taught to fetch a wounded Bird out of a river, or to start Hares which lay hid in the long grass. A clever Dog would be valued, and kept, and

some of its descendants would be a little cleverer than usual. At last, Man found out that the Dog can be made into a faithful and most useful companion. There are some savages who care more for their Dogs than for their babies.

Uses of the Dog.—Let me tell you of some of the uses to which Dogs have been put.

They have been taught to hunt, to pick up game, to *point* at game—that is, to stop, and look steadily towards



Fig. 167.—POINTER.

the place where a Bird is hiding. They point by smell, and often point at the place which a Bird has left.

The Eskimo teach their Dogs to draw sledges, and bring home the game which the hunters have killed.

Dogs have been taught to keep the house, and to bark at robbers. A man will lay his coat on the ground, and tell his Dog to watch it, and the Dog will allow no one to touch it, or even to come near.

They have been taught to mind Sheep. A Sheep-dog

understands all his master's cries and signs, and will drive the Sheep this way or that, as he is bid. In some of the great Sheep-pastures of South America, one or more Dogs are left alone with large flocks of Sheep, and they never lose any of the Sheep, or let them wander far.

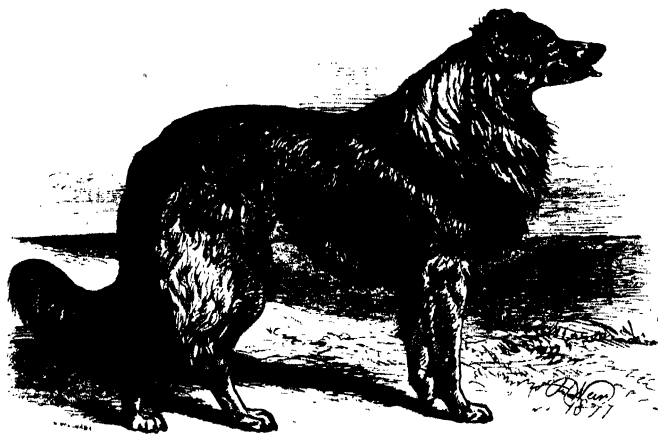


Fig. 68.—COLLEY OR SHEEP-DOG.

They come home for food, and return immediately to the flock.

Dogs are very fond of society. Many Dogs are glad to see their master's friends. They like to meet other Dogs, though they sometimes quarrel when they meet.

Where our Domestic Animals come from.—Many of our domestic animals were tamed long ages ago in Asia, and have been carried by Man to other countries. We should have very few useful animals, if we had not shared with our neighbours. We should have had the Ox and the Dog, and probably the Horse, besides a great bristly

long-legged Pig ; but no Sheep, or Goat, or Ass, or Cat. We might have had tame Pigeons, and Geese, and Ducks, but we should have had no Fowls.

The Rabbit was brought from the south of Europe.

The Sheep and Goat probably came from Asia, but so long ago that nothing is known for certain about their native country.

The Cat which lives in our houses is not the same as the Wild Cat, which formerly used to roam in our woods, and which is still to be found in parts of Scotland. Our domestic Cat came from the East, and was first brought to England about seven hundred years ago. The Greeks and Romans had no Cats, but kept Weasels or Martens in their houses to rid them of Rats and Mice.

The Fowl was brought from India, the Canary from the Canary Islands, Gold Fish and Silkworms from China.

Very few domestic animals have come from the New World ; we have, however, got the Turkey from Mexico. Before America was visited by Europeans, it was very badly off for domestic animals. The Indians had Dogs, but no Horses, or Oxen, or Pigs, or Sheep, or Cats, or Rabbits. The natives of Mexico are believed to have kept tame Turkeys before the Spaniards landed.



Fig. 69.—RICE.

Useful Plants.—Man has not only found out many useful animals, but he has also found out many useful

plants. Some of these are not cultivated ; they are merely cut down or gathered when wanted. Others, like timber trees, are planted, and then left to shift for themselves. But there are many which require a great deal of attention. They must have a place kept for them ; they must be sown, and manured, and weeded, if they are to be of any use. We call these *cultivated plants*. Let us think of a few.



Fig. 70.—SUGAR-CANE, WITH PART OF THE STEM ENLARGED.

Grain.—First come the different kinds of GRAIN, which

are all the seeds of Grasses. I suppose that the most important are Wheat, Barley, Oats, Rye, Rice, and Maize.



Fig. 71.—TEA-PLANT.

Vegetables.—Then come the VEGETABLES, such as Potatoes, Cabbages, Turnips, Peas and Beans, Rhubarb, and Onions.

the **FRUITS** we have Apples, Pears, Grapes, Plums, Cherries, Strawberries, Raspberries, Gooseberries, Oranges, Pine-apples, Walnuts, Hazel-nuts, Peaches, Apricots.

Fibres.—Some plants are cultivated for the useful **FIBRES** which they yield, such as the Cotton Plant, Flax, Hemp, Jute.

Other useful Plants.—There are still many useful plants to be mentioned. The Sugar-cane and Beetroot yield us sugar. Tea, Coffee, Spices, most Drugs, and many important Dyes, come from cultivated plants.

Much improved by Man.—Nearly all these useful plants have been greatly improved by Man. Cultivation



Fig. 72.—COFFEE-PLANT.

in rich, well-manured soil, and careful weeding, make plants stronger and larger. Whenever an improved sort springs up, it is eagerly selected for raising seed, and the worse kinds are sown no longer. You would hardly know the wild

our valuable vegetables and fruit, if you were to see them. Wild grain of all kinds is small and poor; wild fruits of all kinds are poor, no better than the Blackberries and Crab-apples in our hedges.

Many useful Plants have become varied.—By cultivation and selection many useful varieties of the same wild plant have been got, and sometimes these are quite unlike one another, as well as very different from the wild stock. We shall best understand how far it is possible to go in the way of breaking up one natural *species*, or kind of plant, into distinct varieties by taking an example. Let us see what has been done with the Cabbage.

History of the Cabbage.—The wild Cabbage is a rather uncommon plant which grows on the sea-coast. It is nearly two feet high. The leaves are large and ragged. The stem is tough and woody. The flowers are of a pale yellow colour, and contain small pods, which afterwards enlarge, ripen, and form the fruit. This plant is not very tempting, but it is wholesome; and long ago the early races who inhabited the shores of Europe found out that it was worth cultivation. It was very likely tried for the first time when food was scarce, and was found to be harmless, and nourishing, and not unpleasant in taste. By-and-by, some man, a little more thoughtful than his fellows, would plant some Cabbages near his hut or cave. The next step would perhaps be to raise them from seed, and to manure the ground in which they were planted. When sowing the seed became common, improved sorts would be noticed, and preferred to the rest. One man would say to another, "Give me a handful of your Cabbage-seed, for it produces better plants than mine." Some people would value seed which produced leaves crowded together into close, fleshy balls. Others would prefer their Cabbage with as little stalk as possible, and would find out the short-stalked plants to save seed from. We can now see for ourselves what is the result of many hundreds of years of careful selection.

Different sorts of Cabbages.—The original wild Cabbage is believed to have been the parent of all the following sorts :—

The common green Cabbage, with a short stalk, and a great round mass of leaves wrapped as closely together as possible.

The red Cabbage, with purple-red leaves.

The Cauliflower, with a crowd of small, imperfect flowers, few of which ripen any seeds.

Brussels Sprouts, with long, branched stems, and very many small Cabbages springing from them here and there.

Broccoli, with curly leaves.

There are many other sorts which I need not trouble you with. Perhaps the Turnip comes from the same wild Sea-cabbage, or a plant very like it.

What Cabbages have done for Man.—The Cabbage has perhaps done as much for man as man has done for the Cabbage. It provided him with plenty of wholesome food, nearly always to be had even when fish and flesh and grain happened to fail. It helped him to turn gardener and farmer, instead of spending all his time in hunting and fishing.

It seems at first sight a pleasant thing to hunt and fish all day. Perhaps some of you think it would be a fine life to lead. But you have never tried it for yourselves.

Life without Domestic Animals or Cultivated Plants.—In a country where there are no fields or enclosed spaces, and where many people, as well as a host of wild animals, live by hunting, game grows scarce. The hunter has to walk miles to get a chance of a Stag, and he has only poor weapons in his hand, for he has to make everything for himself. His arrow, or spear, is a poor thing in

comparison with a rifle. It often misses, and when it hits, it often fails to kill. Our rude forefathers, like some savages of the present day, must have found it hard work to keep themselves alive at all. Even hunting is not very amusing when you have to hunt all day and every day, just to get enough flesh to eat. There is no time to build a comfortable house, or to smelt metals, or to dig coal. Perhaps in the long winter nights the hunter will make himself shoes, and a handsome cap, and a new bow and arrows, but no great works, for which many hands are required, can ever be attempted. So long as men get their living entirely by hunting and fishing, they cannot do much to improve their lot. But when they learn the use of domestic animals and cultivated plants, they are set free. There are the

sheep penned up in the field; we can have mutton to eat when it is wanted. There are the cabbages growing in the garden; we can boil a dish of vegetables whenever we are hungry. Let us go into the wood, and fell trees, and cut some beams to



Fig. 73.—COB OF MAIZE.

make a better roof over our heads. Our women need not go down to the sea-shore to gather mussels; let them make us some new clothes. Mutton and Cabbages mean a great saving of time, and that means a better way of living,

and steady improvement in all the useful arts. Villages and towns, and regular government, and writing, are possible to men who have mutton and cabbages; they are not possible to men who live by hunting and fishing.

Useful Plants of the Old and New Worlds.—

Nearly all our most useful plants come from the Old World, but we owe the Potato, Maize or Indian Corn, Cocoa, and the Pine-apple, to America. Much of our sugar is now grown in America, but the sugar-cane came originally from the East. It was brought to Europe by the Crusaders, and was taken over in ships, first to the Canary Islands, and afterwards to America. Perhaps the most precious gift which America has made to the Old World is quinine, a drug which cures many kinds of fever and ague. It is obtained from the bark of a small ever-green tree, which grows wild in South America, and is now cultivated in India.

LESSON X.

THE PRIMROSE.—HOW PLANTS SET THEIR SEED.

WANTED:—*Two Primrose Plants in flower, one long-styled, the other short-styled. A number of cut Primrose flowers. Large models, cut out of coloured paper, will be useful in explaining the parts of the flower, and the two forms found in the Primrose. A pocket lens, two or three needles, mounted in sticks, and a sharp knife, should be at hand.*

Shape of Leaves.—Here is a Primrose Plant. Notice its large leaves, which look wrinkled, because of the strong veins which stand out from their under side. The leaves

widen out towards the tip. Why is that? You often see leaves of this shape in plants which form rosettes. It is important that the leaves should not get in one another's way, or shade one another. For this reason the leaves of a rosette must be narrow at the base, but they may widen out as they get away from the root or main stem, where there is more room for them. This figure will show you that if I draw a number of circles one outside another at equal distances, each ring occupies more space than the one inside. The triangles in the figure are very nearly equal to each other. In the innermost circle there is only one triangle; in the next ring there

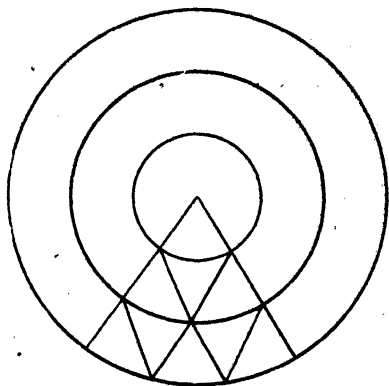


Fig. 74.—SPACES OCCUPIED BY SUCCESSIVE RINGS, ONE ENCLOSING ANOTHER.

are three; in the next five; in the next there would be seven, and so on. Calculation shows that the area of the rings goes on increasing *exactly* in the proportion of 1, 3, 5, 7, etc., so that the leaves may, if they like, widen out at the same rate.

Veins of Leaves.—Notice next that the strong veins on the under side of the leaf are branched, and form a network. Why is this? If you think a moment, you will see that there is very little room for them at the base of the leaf, and much more room farther away from the base. The veins have to bring fluids to the leaf, and take other fluids away, and it is necessary that they should be fairly

spaced at nearly equal distances, otherwise some parts of the leaf would be made up of nothing but veins, while other parts would be practically without veins at all. See what would happen if the veins took a straight course without branching. The veins would be much crowded towards the base. But if the veins are allowed to branch,

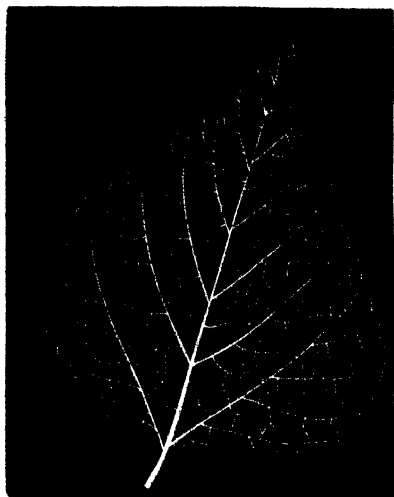


Fig. 75.—LEAF-VEINS OF BLACK
POPLAR.

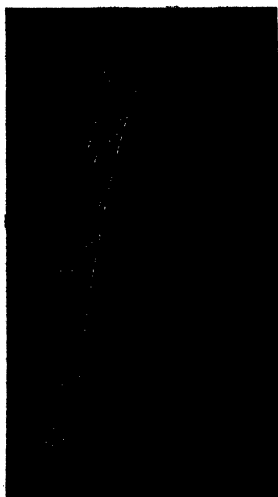


Fig. 76.—LEAF-VEINS OF
DAFFODIL.

as in Fig. 75, they can be spaced pretty equally. If the leaf were strap-shaped, and not narrowed at the base, the veins might run side by side without branching.

Hyacinths, Daffodils, Lilies, and other plants with leaves of this shape, not narrowed at the base, have straight unbranched veins. (See Fig. 76.)

Flower Stalks.—The flowers of the Primrose stand up

in a bunch in the midst of the leaves, each on a separate stalk. In the Cowslip all these stalks spring from a strong stem in the centre. If you look at the Primrose carefully, you will see that its flowers are really arranged in the same way as in the Cowslip, but the central stem is so short that it cannot be seen without close attention.

Outer parts of the Flower.—Each flower of the Primrose consists of an outer green cup, which is rather small, and of an inner yellow cup which is much larger. Botanists call the outer cup the *calyx*, and the inner cup the *corolla*. The calyx is folded and has five strong plaits, as you see. What do these mean? They mean, I believe, that the calyx had to be folded up in the bud into the least possible space, and it was folded into five plaits, so as to look like a five-pointed star when cut across. (See Fig. 77.) This star shape has one special advantage. The Primrose flower contains sweet juice, and eatable grains of pollen and seeds, which Insects know of and try to reach. They would soon eat them up if they once got inside. Some of them try one way and some another. Flying Insects make their way in by the tube of the corolla, but this entrance is so long and narrow that most of them can only stand outside, and thrust their long tongues into the tube and suck up the juice. Those that have no long tongue try to get at the tempting dainties by biting holes

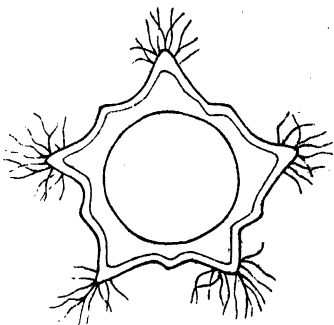


Fig. 77.—SECTION THROUGH CALYX OF PRIMROSE.

in the calyx. I fancy that they are much disappointed when they have bitten a hole into the calyx to find that they have only broken into an outer chamber filled with air, and that the corolla is still untouched and inconveniently far off for their short jaws. These gnawing Insects are sure to bite through the calyx, not along the hollows, which are hard to get at, but along one of the projecting ridges, and here the calyx is far from the corolla. The Primrose may be said to keep a sweet shop. Visitors are welcome if they come in by the door, and pay their penny. But they are not at all welcome if they try to break a hole in the window and put their hands in. They will find that there is an inner window, and that all the sweets are kept behind it. Who are the visitors who pay for sweets to the Primrose? I will tell you by-and-by.

The yellow corolla has a deep narrow tube, and spreads out above into a flattish lip which is divided into five lobes. Why is the corolla spread out wide at the top? In order that it may be plainly seen. It is of no use to keep a sweet shop unless people know where it is. Why is the corolla narrow below? To keep out thieves, and allow no one to come in except by one particular way. Is there some one standing there to take pennies? No, but the Insect which comes in by the right way will have to do something in return for the sweets which it gets. We shall see how this is managed.

Inner parts of the Flower: the Stamens.—Now we must examine the inside of the corolla. I remove one carefully from a flower, slit it open with a fine pair of scissors, taking care to cut between two lobes, and fasten it to a gummed card as flat as possible. I will send the card round so that you can all see. Towards the top of the

tube of the corolla are some little knobs, one to every lobe. These are called *anthers*. The anthers are generally carried on long stalks, or *filaments*, and the anthers and filaments together make up a *stamen*. Here the filaments are so short that you can hardly see them.

Two kinds of Primrose Flowers.—All Primrose flowers have not the stamens in the same place.

The flower which we opened just now had the anthers at the top of the tube, but here is one which has the anthers half way down the tube. I will open it as before, and send it round. Look at your own flowers. You will find some of one kind and some of the other, but all the flowers on one plant

are of the same kind. How many stamens has the Primrose? Five; just the number of the lobes of the corolla. If you look carefully you will find that every stamen comes exactly opposite to a lobe. This is not often the case with flowers, but it is so in all Primroses.

The Pistil.—There is still something left in the flower. Standing up in the very centre is a long thread with a knob at the top. It rises out of a round body at the very bottom of the corolla tube. This central

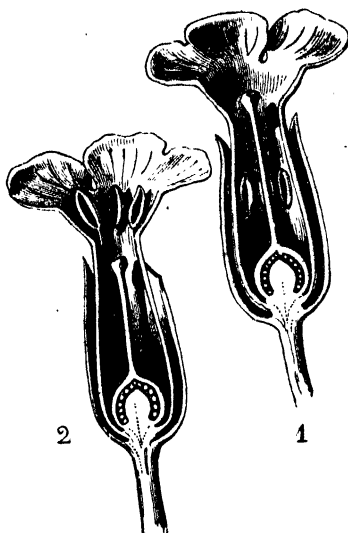


Fig. 78.—FLOWERS OF (1) LONG-STYLED AND (2) SHORT-STYLED PRIMROSE, CUT OPEN.

part of the flower is the *pistil* ; it consists of three parts : the *ovary* at the bottom, the *style*, or long stalk in the middle, and the *stigma*, or knob at the top. I have mentioned a number of new words to you, and before we go any farther let us see if you remember them. Point out the calyx, corolla, stamens, and pistil ; the anther, ovary, style, and stigma.

Long-styled and Short-styled Primroses.—We have seen that there are two kinds of flowers in the Primrose. One kind has the stamens at the top of the corolla tube ; the other has the stamens half way down. The first kind has a short pistil only reaching half way up the tube ; the second kind has a long pistil reaching to the top of the tube. In the first kind you will see the anthers at the top of the tube ; in the second kind you will see no anthers, but the round knob of the stigma. We may call these two kinds of flower *short-styled* and *long-styled*.

Where the Seeds are formed.—What is the use of the ovary ? If I tear open the ovary with a needle, and look at it through a pocket lens, I see a great number of small, white, unripe seeds in it. The ovary is the part of the flower which produces the seeds. What is the use of the style and stigma ? What is the use of the anthers ? These questions are not quite so easy to answer.

Insects necessary to Primroses.—If a Primrose-plant ready to flower were put under a glass shade and kept there, it would ripen no seed. The seeds would grow to a certain point, and then they would wither and dry up. What has the glass done to prevent the seeds from ripening ? It has not spoilt the seeds by keeping out light or air, as you might be inclined to suppose, for you may let in as much air and light as you think necessary, and

still no seeds will ripen. But you must take care not to admit Insects, if you wish to prevent the seeds from ripening.

What would the Insects do? They would make the seeds fertile—that is, able to grow into plants. Instead of withering and drying up, the seeds would swell and grow, and in time would be ready to spring up in the ground and bring forth new Primroses. How do the Insects make seeds fertile?

Pollen and Pollen-tubes.—Inside each anther is a quantity of fine yellow dust. If you see this fine dust, or pollen, as it is called, through the microscope, you will find that it consists of regular oval grains. When grains of pollen are placed on a damp surface, they swell, and burst, and put forth long threads, or tubes. If they are placed on the stigma, they send these long tubes down the inside of the style, till at length they reach the little undeveloped seeds in the ovary. Unless the seeds are touched by the ends of the pollen-tubes they never ripen; but when the pollen-tubes reach them, they become fertile. No one knows exactly what the pollen-tubes do to the seeds. Though the microscope allows us to see the pollen-tubes entering the seeds, it does not make plain to us all that goes on inside. We hardly know more about it than that the pollen-tubes carry something to the seeds which is necessary for their ripening. Even when we have examined and studied the ways of Nature as carefully and patiently as possible, there is generally something left which we cannot get to understand with all our pains.

What the Flowers do for the Insects.—What the Insects do is to carry grains of pollen from the anthers to the stigma, and leave them sticking there. Do they know

what they are doing? Do they mean to fertilise the seeds? No, they neither know nor care anything about it. They dust themselves with the pollen, and

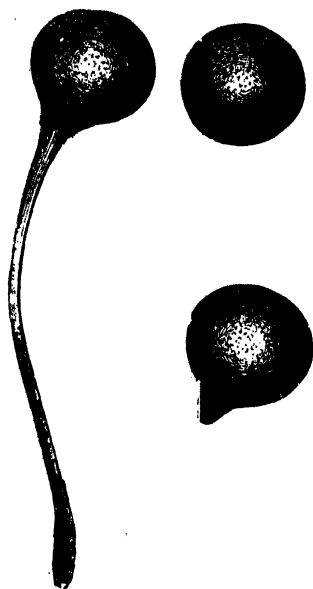


Fig. 79.—POLLEN-GRAINS AND
POLLEN-TUBE (MAGNIFIED).

(The pollen grains of the Primrose are oval.)

afterwards brush it off against the stigma. This is the toll which the Insects have to pay. In return for the sweet juice which they find in the flower, they have to fertilise the seeds. The flower is so made that the Insects do their work whether they mean it or not.

Primrose Pollen always brought from another Plant.

— But there is one other thing which I must tell you of, in order that you may understand how beautifully the Primrose-flower is contrived to answer its purpose. In many plants the pollen must always be carried from one flower to another, and to a flower growing on a different

plant. The seeds are of no use unless they have been fertilised by pollen brought from another plant. I cannot tell you why this is sometimes necessary, but not always. There are some flowers which can be fertilised by their own pollen. There are others which will set no seed unless they are fertilised by pollen from another plant. The Primrose is one of these last.

How Insects carry Pollen from one Primrose to another.—Now we will see what happens when an Insect, such as a Bee, flies to a Primrose-flower. He sees the flower a long way off, and flies towards it. Then he gets astride of the flower, and opens out his long tongue, which is folded up, when not in use, into three pieces, something like a pocket foot-rule; then he pushes his tongue into the tube of the corolla. His head is too big to go in, but the long slender tongue will reach to the bottom. He searches for the sweet juice of the flower, and in doing so dusts his head or his tongue with the pollen. It depends upon the kind of Primrose visited which of the two will be dusted. If it is a short-styled flower, he will dust his head; for in a short-styled flower the anthers are at the top. If it is a long-styled flower, he will get the middle part of his tongue dusted, for you remember that in such flowers the anthers are half-way down the tube. We will suppose that he first visits a short-styled flower, and afterwards a long-styled one. The first Primrose dusts the Bee's head; the next has the stigma at the top ready to catch the pollen from his head. This second Primrose dusts the Bee's tongue half-way down. When he comes again to a short-styled Primrose, the same part of his tongue brushes against the stigma, and so he goes on carrying pollen from one flower to another, from long-styled to short-styled, and from short-styled to long-styled; but never from long-styled to long-styled, or from short-styled to short-styled. All the flowers on one Primrose plant are of the same kind. You see, therefore, that the Bee can never carry pollen from the anthers to the pistil of the same flower, nor to any flower like it. He can only carry it to a flower of the other kind, and this must have grown on a different plant.

You must go over this two or three times in order that you may understand it perfectly.

Bees and some other Insects are busy all day long sucking the flowers. Some plants are wasteful with their pollen, but the Primrose is very careful; and a great part of it is put to its proper purpose—that is, the fertilising of Primrose-seeds. But some pollen gets carried by mistake to wrong plants, such as Campions, or Pansies, and then it is wasted, for no pollen will fertilise the seeds of a quite different flower. The Bee eats some, and carries some away to the hive.

What happens after the Flowers are fertilised.—When the flowers have been fertilised, the corolla and stamens fall off, and the stigma itself withers not long after. The ovary grows bigger, because all the seeds are ripening inside it. When the seeds are ripe, the ovary bursts open at the top, and the seeds are scattered. Those which fall into likely places spring up, and produce new Primrose-plants.

LESSON XI.

THE PANSY.

WANTED:—*Flowers and Seed-vessels of Pansy.*
A few peas.

Outer parts of the Flower.—To-day we will examine a Pansy. It has a large, gay flower, which droops a little on its long stalk, and always turns its face to the sun. You can easily see the calyx at the back of the flower. It is made up of five leaves, which are called *sepals*. The corolla is brightly coloured, purple or yellow, or partly

purple, and partly yellow. It is made up of five leaves, called *petals*.

Colours of Pansies.—Do you remember what we said about the colour of Rabbits? The wild animal is tolerably uniform in colour, but the tame ones are very various. One particular colour is best suited to the wild animal, which has many enemies to avoid, but people who keep tame animals fancy different colours, and they can get nearly every colour which they think pretty. How? By picking out and preserving those young ones which are most to their taste, and getting rid of the rest. In the same way, that is, by continual selection, men have been able to get Pansies and Dahlias and other flowers in a great variety of colours. The gardener takes seeds or cuttings from what he considers the pretty sorts, and throws away those which he considers ugly. One gardener likes yellow Pansies best, and weeds out all that are blue; another prefers blue Pansies, and weeds out all the yellow ones. In course of time each gets what he requires. Even wild Pansies are not exactly alike, but Pansies in gardens become much more varied. Blotched or parti-coloured Pansies can easily be got. If you put the pollen of a yellow Pansy upon the stigma of a purple one, the seeds which are borne by the purple Pansy will produce parti-coloured flowers, partly yellow and partly purple. Many curious tricks can be played with flowers in this way.

The Petals—one spurred.—Pull a flower to pieces, and separate the five sepals and the five petals. Notice that one of the petals has a long hollow spur. What is this for? Depend upon it, the spur has some useful purpose, or it would not be so large, nor would it be found in every Pansy.

The Stamens—two with long arms.—Let us next look for the stamens. They are not carried on the corolla this time, as they were in the Primrose. After all the petals, or corolla-leaves, have been pulled off, the stamens remain behind, standing out close together in the middle of the flower. Notice that two of the anthers are furnished with very long and narrow arms. Before we pulled the flower to pieces these two arms were enclosed in the hollow spur of one of the petals. What are the long arms for? We shall learn shortly.

The anthers of the Pansy do not burst outwards, as most anthers do, but inwards, and the loose pollen falls into a space which is enclosed by the anthers. The bottom of this space is closed by five orange-coloured flaps, which project from the ends of the anthers, and the stigma passes out between them.

The Pistil.—Now take off the stamens one by one, as carefully as you can, with a needle or the point of a pen-knife. A greenish object of curious shape is found in the middle of the flower. This is the pistil. It has an ovary or seed-vessel at its base, a rather short style, and a knob at the end, which is the stigma. The stigma may always be seen in a fully-opened flower, pushing through the ring of anthers, and standing out in front of them.



Fig. 80.—PISTIL
OF PANSY.
n, Hollow stigma.

Honey in the Flowers.—Which petal carries the long spur? The lower one. Carefully slit open the spur with a pair of scissors or a sharp knife. A very small drop of fluid is often found in the end of the spur, and this fluid is sweet and sugary. It is honey. We can only just distinguish

its sweet taste, for there is so little of it, but a small creature, like an Insect, would find it a great treat. Bees are fond of sucking up the juice from the spur with their long tongues. Where does the honey come from? You cannot make out by common eyesight, but if you search with a microscope you will find honey-forming glands on the long arms, which reach into the spur from two of the anthers. As the honey is distilled from these glands it drops into the hollow end of the spur.

How the Pollen is carried off by Bees.—Look carefully at the part of the lower petal which comes just beneath the anthers. You will see a number of fine hairs, and if the flower has been open a day or two these hairs will be dusted over with pollen. You will find that a Bee trying to get at the honey in the spur will be certain to brush against these hairs, and carry some of the pollen away on its tongue. It is easy to guess where the pollen comes from. The anthers which produce the pollen are just above, and when they burst and shed their pollen it falls into the enclosed space round about the stigma. The stigma stands out in the throat of the flower, right in the path of any Insect which tries to suck the honey, and whenever the stigma is pushed on one side, pollen falls out of the enclosed space within the anthers and lodges on the hairs.

How the Pollen is lodged on the Stigma.—It is necessary that this pollen should somehow be brought to the sticky surface of the stigma, and left there. It is also important, though we cannot tell why, that the



Fig. 81.—PISTIL AND ANTERS OF PANSY.
h, Two long arms.

should be carried to another flower, and not be left on the stigma of the flower which produced it. I will try to explain how this is managed. The stigma, which looks at first sight like a solid knob, is really hollow, and the sticky surface intended to catch the pollen is inside it. There is a small hole on the under side of the stigma, which you can just see if you have sharp eyes, and this hole seems made on purpose to let the pollen in. Below the hole is a soft, sticky lip which hangs down. You will see the parts much better if you look at the stigma with a pocket magnifying glass.

When you are quite sure that you understand how the stigma is made, I will try to tell you how it acts. If no Insects visit the flower no pollen will reach the inside of the hollow stigma, except by chance. But if a Bee comes and thrusts its long tongue into the spur in search of

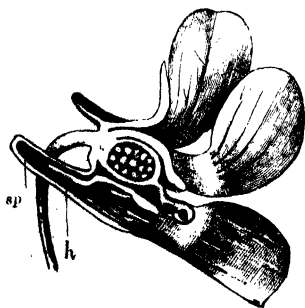


Fig. 82.—SECTION OF PANSY-FLOWER.

sp, Spur; *h*, long arm of anther.

honey, everything will go as it should. First of all, the Bee will dust its tongue with the pollen, which lies on the hairs beneath the anthers. When it draws back its head the tongue will push against the hanging lip, but none of the pollen just taken up from the hairs will get inside the stigma, for the tongue has brushed against the *back* of the lip, which looks away from the opening.

Next the Bee flies away, carrying a number of pollen-grains on his hairy tongue. He visits another Pansy, longing for more honey, and caring nothing about the setting of the

Pansy's seeds, of which he never heard in his life. He pushes his tongue along the well-known passage, and in doing so brushes the *front* side of the hanging lip. Some of the loose pollen is left behind on the lip ; on the *front* side, remember, this time.

Thus from time to time pollen taken from other flowers is left on the *front* of the lip. Pollen removed from the same flower is left on the *back* of the lip if it hits the stigma at all. The pollen-grains which lodge on the front of the lip, and those which get pushed into the hollow stigma, get wetted with the sticky fluid which oozes from the stigma. Then they swell, send out their tubes through the style, and fertilise the seeds. You see that all the pollen gathered from the same flower as that which carries the stigma is left outside the stigma. Every grain which enters the stigma comes from another flower.

Questions.—I will ask you a few questions to make sure that you have followed these explanations. Why are the flowers of the Pansy large and gaily coloured? To attract the attention of Bees. Why is honey formed and distilled into the spur? To tempt Bees to thrust their tongues into the spur. What is the use of the hairs on the lower petal? To catch the loose pollen-grains, and keep them ready just where they are certain to dust the Bee's tongue. Why is the stigma hollow and furnished with a lip? So that no pollen may enter it except that brought by Bees from another flower. Why must the pollen be brought from another flower? I cannot tell, but so many flowers have ingenious contrivances to make sure that they shall be fertilised from another flower of the same species, that this is plainly a very important point. Nature teaches

us this, we should hardly have guessed it for ourselves. Some flowers are always fertilised from others; we call these *cross-fertilised*. Others are sometimes fertilised by their own pollen, and are then said to be *self-fertilised*. But there is, perhaps, no plant which is always self-fertilised.

The Tongue of a Bee.—Why has a Bee a long hairy tongue? To suck up sweet juices. The hairs serve to collect small drops of fluid sticking to some parts of the flower, but not big enough to be sucked up. The tongue is strap-shaped, and can either have its edges bent inwards so



Fig. 83.—HEAD OF WILD BEE, WITH THE MOUTH-PARTS SPREAD OUT.

as to form a tube, or opened a little way for cleaning, if it should become clogged. Besides the long tongue, a Bee has feelers, blades, and a pair of strong nippers attached to the mouth. There are also eyes and a longer pair of feelers on the head. The long feelers, carried on the forehead, can be used for smelling as well as feeling, and thus the Bee is provided with all the instruments it requires to suck up sweet juices. There are eyes to see the flower, a smelling organ (we cannot call it a nose) on the long feelers; nippers to bite anything hard, a pair of thinner plates which can be

worked like a pair of scissors, only not as a rule to cut, but to separate and stretch the sides of an opening, a pair of small feelers, used like finger-tips, to handle

objects, and lastly, a long, delicate tongue, which can suck up sweet juices from the innermost corners of flowers. Here is a picture of the Bee's head, with all the parts drawn out as far as they will go. They can be folded up into a very small space when not in use, very much in the same way that a foot-rule is folded up. Take a long strip of paper and mark it out into three equal parts. At the first mark bend the paper into a sharp fold, at the second mark, bend it in the opposite direction. That is how a Bee folds its tongue, before tucking it away under its chin.

How the Pansy scatters its Seeds.—When the flower of the Pansy has been fertilised, the petals and stamens and style fall off, and the seeds begin to ripen. After a few weeks the ovary will have grown many times larger than it was at first, and it will then be quite easy to see its shape. It is almost egg-shaped, but pointed at the end which comes uppermost. Inside the ovary are three upright rows of hard, round seeds. When the seeds are hard and ripe, the ovary splits down the sides in three places, and thus becomes divided into three valves, which separate from each other, and bend outwards. Each valve has a row of seeds lying along it, and when the valves separate, the seeds dry in the air, and are soon ready to be sown. We should perhaps expect that they would simply drop to the earth, and afterwards spring up as young Pansies. But that simple plan would not work well. Perhaps a hundred young Pansies would be lying at the roots of the parent plant, overshadowed by its broad leaves, and crowded together as close as they could stick. I am not sure that a single one would survive and manage to flower, but I am quite sure that nearly all would perish very soon. If a fair number of seedlings are to be reared, the seeds must be

scattered. The Pansy has found this out, and it has also found out a very successful way of shooting its seeds to a distance. Each of the valves which I told you of is shaped like a boat. It has two curved sides, a point at one end, and a hollow space between the two sides. The inside of the boat is filled with the round hard seeds. After the ovary has separated into three valves, the sides of each valve gradually straighten themselves, and as they are fastened together at both ends, they must gradually get nearer together as they straighten. You can imitate this action very well with your own hands. First put both hands together as if you were making them into a cup to drink out of. Then gradually straighten your fingers until the palms of your hands meet. That is just the action of the valves of the ovary. I believe it is caused by the slow drying of the valves. It takes place very slowly, and lasts several hours. As the valves come together they press the seeds harder and harder, until first one seed and then

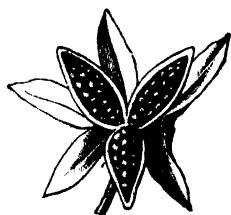


Fig. 84.—FRUIT OF PANSY,
AFTER BURSTING, BUT
BEFORE THE SEEDS ARE
SCATTERED.

another slips suddenly out, and is shot to a distance. When I was a schoolboy we used to play a trick with peas, which was managed in the same way. A pea was put on the desk, the edge of a book was brought down upon the top of the pea and pressed hard against it. By rolling the pea a very little way it could be suddenly released, and

our joy was great if it happened to hit a school-fellow, or bang against a window-pane. The Pansy shoots its seeds a long way. I remember putting a ripe ovary on the table to see it empty out all its seeds. As I sat writing,

I now and then heard a very faint sound, like a crack or tap. It was a seed hitting the inkstand or the wall. At the end of the day there were no seeds left. If you put a ripe ovary of the Pansy on a large table, and leave it for a few hours, you will not find a single seed either in the ovary or on the table.* All have been shot to a distance.

The Pansy fires off its seeds in this way, one by one, and in all directions. No doubt many fall upon unsuitable places, and never spring up, but some find good places, and sprout, and turn into Pansy plants.

LESSON XII.

THE ORCHIS.

WANTED :—*Common Orchids in flower. One should be dug up by the root.*

Different wild Orchids.—We have several wild Orchids, which are not uncommon in early summer. The easiest to find are the *Green-winged Orchis*, the *Early Purple Orchis*, and the *Hand Orchis*. This last is generally called the *Spotted Orchis*, which is not a good name, because the Early Purple is spotted too. I will tell you by-and-by how it got the old name of *Hand Orchis*.

You can tell the *Green-winged Orchis* by the green veins on the petals. The other two usually have dark spots on the leaves. The Early Purple is larger and handsomer than the *Hand Orchis*. The flower is redder and less spotty. Any one of the three will do for our purpose.

* The same experiment may be tried more rapidly by holding a nearly ripe ovary in front of the fire.

Knobs on the Roots.—I have brought you a plant dug up by the roots, so that you may see the knobs upon them. Notice the shape of these knobs. They are nearly round in the Green-winged and Early Purple Orchis, but

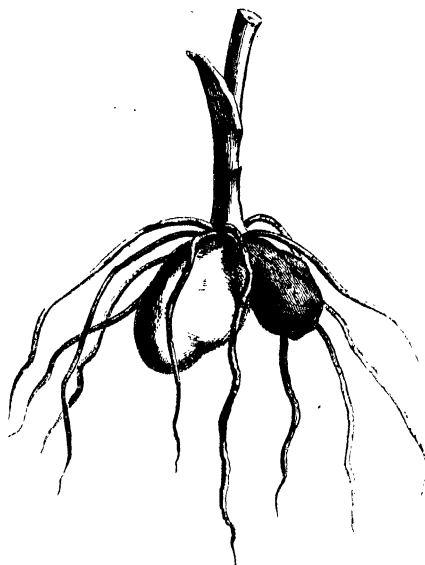


Fig. 85.—ROOT OF EARLY PURPLE ORCHIS.

The old, empty knob is shaded.

branched in the Hand Orchis. The branches look a little like fingers spreading out from a palm, and this suggested the name of *Hand Orchis*.

What is the use of the knobs on the roots? There are two of them side by side. The stem with its leaves and flowers grows out of one. Next year's stem will grow out of the second. If you press between your finger and

thumb the one which now bears stem and leaves, you will find that it feels thin and soft, the other is firm and thick. I cut each across with a sharp knife: one is spongy and contains some air, the other is solid. The fact is that the knob intended for use next year is full of food; the older knob, out of which a stem has already grown, has been emptied of its food. The food consists of *starch*, and some day I will tell you how you can satisfy yourself that it is



Fig. 86.—HAND ORCHIS.

really starch, and that one knob contains much starch and the other hardly any, but we are not ready for this yet. Many plants store up food in their roots for future use. They can form plenty of food in summer, and little or none in winter, for reasons which you will understand better when I have explained to you how plants feed. When winter comes on, the Orchis has a good store of food laid up, and it lives upon this when all its leaves are dead, and nothing appears above ground. It not only lives, but it gets ready a new spike of flowers, and is ready to push up in all its glory as soon as the sun shines bright next spring. Hyacinths and Crocuses and many other plants do the same thing, and hence they are able to flower whenever it suits them best, without waiting for summer heat to feed them up. I think you will now see why the Orchis has two knobs on its roots, one spent and the other fast filling with starch.

Orchis Leaves.—The leaves of the Orchis are dark and glossy, and spotted in some species. They are different in shape from the leaves of the Primrose and Pansy. Orchis leaves are long and very often as broad at the base as anywhere else. In consequence of this the veins are not obliged to branch, but run side by side all the way. Stalked leaves, and all leaves which are narrow at the base, have *branched* veins. Sheathing leaves, which clasp the stems, or one another, and are as wide at the base as anywhere else, may have straight or *parallel* veins.

Outer parts of the Flower.—The sepals and petals of an Orchid are arranged as in the picture. There are three sepals outside and three petals inside. Each petal comes between two sepals. The sepals are not green in these flowers, but generally of the same colour as the

petals. The lower petal is much larger than the rest. The corolla has a long hollow spur which stands out at the back of the flower. What do you suppose is the use of the spur? If you remember the Pansy, you will be ready to answer that it contains sweet juice as a bribe to Insects, and this is true, but the juice is not so easy to find as in the Pansy.

One Stamen.—There is only one stamen in the Orchis, and this is very peculiar. An ordinary anther consists of two halves joined together, as you see in the anthers of a Lily. But in most Orchids the two halves are separated from each other. They lie at the back of the flower, and each is over-arched by

one of the petals. What does an anther contain? Pollen-grains; and these pollen-grains generally form a loose, dry dust. But in our Orchis they cling together and make what we might call a *pollen-ball*. The pollen-ball has a long stalk which is tipped at the end with a sticky fluid like gum. In an uninjured flower the ends of the two pollen-balls stick out just over the open end of the spur, and they are covered with a thin skin to prevent air getting to them. If they were uncovered the air would dry the sticky fluid in a moment, and then the pollen-balls could not be removed without tearing.

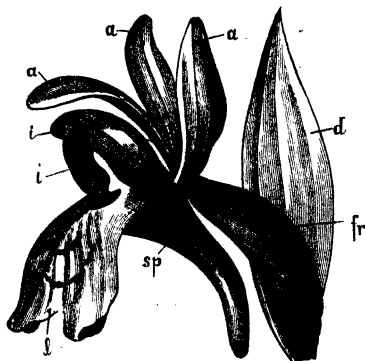


Fig. 87.—FLOWER OF HAND ORCHIS,
SIDE-VIEW (MAGNIFIED).
a, Sepals; i, i, side petals; l, lip; sp, spur;
fr, ovary; d, leaf, partly enclosing the
flower.

Pistil.—The pistil has a stigma and ovary, but no style. The stigma is in an odd place, at the top of the hollow spur, and beneath the projecting ends of the pollen-balls. You can tell it by the glistening appearance of its sticky surface. The ovary looks at first sight like the stalk of the flower. It is greenish in colour in most Orchids

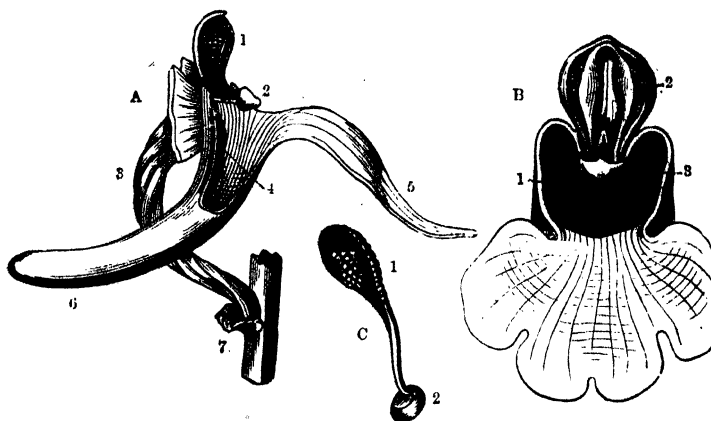


Fig. 88.—EARLY PURPLE ORCHIS.

A, side view of flower, part of which is cut away; 1, pollen-balls; 2, tips of pollen-balls; 4, stigma; 5, lip; 6, spur; 3, ovary. B, front view of flower. C, pollen-ball; 2, its sticky knob.

and always twisted. If you cut the ovary across you will see three rows of small seeds.

How the parts of the Flower are arranged.—It is necessary that you should have a perfectly clear notion of the arrangement of the parts of the flower, or else you will never understand how they act. Let us go over it again, and, to help you a little, we will suppose that everything is very big, as it would appear to a Bee. The Bee, as he flies towards the open flower, sees something like the mouth of

a long narrow cave (hollow spur). In front of the cave is a convenient landing-place (lower petal), and above this is a porch on which are seated two objects, which you can imagine to be men; but which are really the pollen-balls. They are muffled up in chawls, but so that they can spring out in a moment. They sit side by side, but not touching. Their feet are turned towards you, and end in great sticky knobs, as big as foot-balls. Each man has only one foot, and this is covered up, to keep the air from it. Behind and below the men, at the back of the cave, is a place daubed over with a sticky substance (the stigma) which can easily be seen from the front. The ovary is behind, and cannot be seen at all by the Bee.

How Bees carry off the Pollen-balls.—When the Bee approaches the cave he knows what to do. He opens out his long tongue, and pushes it into the long spur as far as it will go. While he is busy exploring the depth of the spur, the projecting ends of the pollen-balls touch his head or the base of his tongue. The thin skin which covers the knobs splits at a touch, and the sticky knobs fasten themselves to the Bee. Now that they are exposed to the air, they set, and grow hard, and in a few seconds they are so firmly attached that the Bee cannot pull them off. By this time the Bee has got all that he wants, and he flies away to another flower, carrying the pollen-balls on his head.

How the Pollen gets to the Stigma.—A curious thing now happens. The stalks of the pollen-balls, as soon as they are well fixed upon the head of the Bee, begin to bend. They bend forward very steadily and slowly, until they point in a different direction from that which they took at first, downwards instead of upwards. In less than a minute the change is complete.

By this time the Bee will have left the spike from which he removed the pollen-balls, and will perhaps have found another Orchid, growing in a different place. He pushes his head in as before. The pollen-balls, owing to their changed directions, now miss the projecting knobs, and hit the stigma beneath. A few pollen-grains are entangled by the sticky surface, and these are left behind when the Bee takes away his head. The Bee works away all day, continually leaving pollen-grains on the stigmas, and now and then removing a pair of pollen-balls from a fresh flower. But he never carries a pollen-ball to the stigma of the flower which produced it. The only possible way of doing so would be for him to fly back to the same flower a minute or so after leaving it. This the Bee never does. He has sucked that flower once, and he finds it more profitable to visit fresh ones.

What brings the Bee to the Flower.—What does the Bee find in the hollow spur? Sweet juice, evidently. But if you look for this sweet juice, you will not find it very easily. The spur is quite empty, and the most careful examination will not bring to light a single drop of fluid. But it has been found that the Bee pricks small holes in the sides of the spur with the points of the cutting blades with which his tongue is furnished, and the sweet juice flows out through the holes. An Insect new to the business would find nothing in the spur, but the Bee knows what to expect, and how to go to work.

Several kinds of Insects haunt the flowers of Orchids. The Early Purple Orchis is fertilised by Humble-bees, the Green-winged Orchis by Hive-bees and Humble-bees, and the Hand Orchis chiefly by Flies. Other Orchids are visited by Moths. Bees and Moths and Flies have often

been captured with pollen-balls sticking to their heads, or eyes, or tongues. When they find a convenient time, the Insects may sometimes be seen tearing off the pollen-balls with their jaws or fore legs.

Experiment. — You can fertilise an Orchis very well for yourselves. Take a pencil or a stout pin, and push it into the spur of a flower, and move it about a little, as if you were searching for honey with it. Then remove it from

the flower. If the flower has not already been visited by an Insect, you will probably bring out one or two pollen-balls fast to the pin. Hold it up, and look carefully to see the pollen-stalks bend forward. Then pass the pin into another flower. You will easily see how the pollen-grains fasten themselves to the stigma.

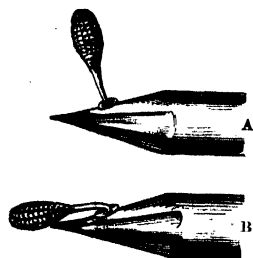
Darwin's Study of Flowers.

Fig. 90.—POLLEN-BALLS OF ORCHIS, REMOVED BY A LEAD-PENCIL.

A, position when first removed;
B, after about a



Fig. 89.—PROBOSCIS OF MOTH, WITH SEVEN PAIRS OF POLLEN-BALLS FASTENED TO IT.



flower of an Orchis act was first completely explained by Charles Darwin. He also showed how Primroses and many other plants are able to get pollen carried from flower to flower by Insects. Darwin found out by actual trial that in many cases a plant produces more seed and stronger seedlings, if fertilised by pollen from another flower than if fertilised

by its own. Those who have read Darwin's books can hardly look at an Orchid without remembering how long and patiently he studied these flowers, and how much he learned from them, which he was afterwards able to teach to others.

LESSON XIII.

THE DANDELION.

WANTED :—*A Dandelion Plant, dug up by the root. Heads, some in flowers, and some in seed. The Model described on page 151.*

Weeds.—I am going to talk to you to-day about one of our commonest weeds—the Dandelion. What do we mean by a weed? I am not quite sure what plants are weeds, and what are not, but I think that we keep this name for such as are ragged and untidy, of no particular use, and of no particular beauty. They are generally very common, and grow fast, and are very apt to show their faces where nobody wants them. I do not think it would be true to say that the Dandelion is an ugly flower. I have seen it look almost handsome in long green grass, and under a bright sun, but it has never been much prized for its good looks that I know of. It has a bitter taste, which has led people to mix it in coffee and certain medicines, but on the whole I am inclined to think that the Dandelion is of more trouble than profit to mankind.

It has a selfish and almost impertinent way of crowding in among better folk. When you want to keep a bit

of turf quite even, or to raise a crop of hay, or to grow grass for your cows, in comes the Dandelion without leave, and plants itself in the best of the ground, and spreads out its ragged leaves. Nothing can grow under them, and when the intruder is at last torn out, a bare patch is left behind. Then there is something provoking in the number of flowers which a Dandelion produces, and in the number of plummy seeds which it scatters to the wind. One Dandelion will infect a whole garden or park. However angry we may be to see Dandelions come up in our choice places, we cannot help admiring their perseverance, and the curious contrivances which enable them to spread so far and so fast.

Root and Leaves.—The Dandelion has a long root, something like a Carrot, but a great deal smaller. This root lodges the plant firmly in the ground, and gives it a safe place in which it can store up food. The leaves spread out in a greedy, selfish way, so as to take up as much space as possible, and choke all near neighbours. The shape of a Dandelion leaf is singular. It has a number of jagged teeth sticking out on each side, and these teeth get larger towards the tip of the leaf. The outline of half a leaf looks a little like the jaw of a Lion, with pointed fangs, and this fancied resemblance suggested the name *Lion's Tooth*, which in French is *Dent-de-Lion*, or as we now call it, *Dandelion*.

Why do the leaves widen towards the tip? Because they form a rosette. You remember that we have worked out that point once before. Why are they cut up into a number of teeth? In order that they may be packed up conveniently in the bud, without awkward folds or crushing.

Milky Juice.—If you break or tear a Dandelion, whether the root or the leaves or the flower-stalk is injured, a milky juice flows out. There is a great deal of it,

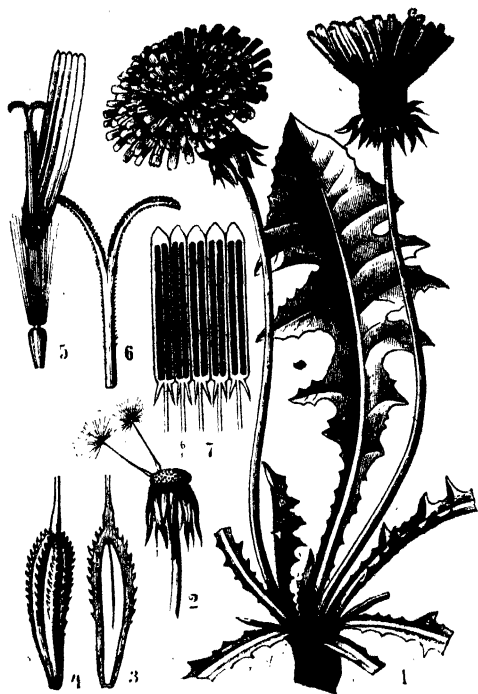


Fig. 91.—DANDELION.

1, Plant in flower; 2, plumed fruits, attached to the stalk; 3, 4, fruit, entire and cut open; 5, a single flower; 6, arms of the style; 7, anthers, spread out.

especially on the lower surface of the wound, and it flows very readily. In a few minutes it hardens, and forms a brown, sticky substance, which gradually becomes quite hard. Taste the milky juice; it has a bitter taste. What

is the use of it? I believe that it prevents animals from gnawing the Dandelion. They do not like its flavour, and small animals do not like to get their mouths choked up with the sticky gum which forms when the juice has begun to dry.

Head of Flowers.—From the midst of the rosette stands up what we commonly call the flower. In this case it is not a single flower, but a head of two hundred or more flowers, all packed close together, and surrounded by a double row of narrow green leaves. These leaves enclose the bud, and keep off rain or frost. Even after the flowers have once opened, they close again on rainy days, and the outer green leaves prevent them from being beaten by storms. It is only when the flowers have fully ripened their seeds that the outer leaves point downwards and begin to fade.

Parts of a single Flower.—Now let us pull off a single flower from the head, and look at it closely. I will fasten some of these small flowers on gummed cards, and send them round. You can easily make out the little white ovary at the very bottom. It contains only a single small seed. The ovary of the Dandelion is completely enclosed by the calyx, which rises up above it. On the rim of the calyx is a fringe of silvery hairs. The corolla can easily be told by its yellow colour. It is a narrow tube, split open along the greater part of one side, and opening out into a flat blade above. At the end of the blade you can perhaps see five teeth, if you have sharp eyes. These are the tips of the five petals of which the corolla is made up. The stamens are found in the tube of the corolla. There are five of them, with five separate stalks, or filaments, but the anthers are joined together,

and make an inner tube. The outermost tube of the flower is formed by the calyx, then comes a tube formed by the corolla, and inside this a third tube formed by the anthers. The long style passes through the anther-tube, in the very middle of the flower, and leads to the ovary below. In a young flower, not yet fully open, the tip of the style can

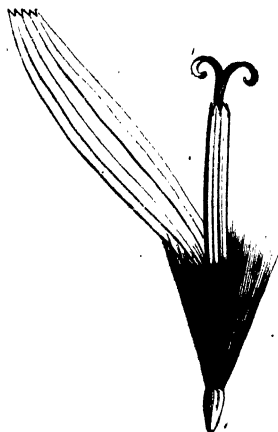


Fig. 92.—A SINGLE FLOWER
OF THE DANDELION.

just be seen peeping through the anther-tube. A little later you may find the style pushing a good way beyond the anthers, and beginning to separate into two arms. When the style has grown to its full length its two arms are clear of the anther-tube, and now they curl outwards, and expose the stigmas. The inside faces of the two arms, which were at first pressed close together, form the stigmas, and these are sticky, as in other flowers, in order to catch pollen-grains.

When the pollen-grains are caught, they burst, and send out long threads, which grow down through the style to the ovary. Only one thread is necessary, for there is only one seed, but we generally find many pollen-grains on the stigmas. I suppose that the first grain which reaches the seed fertilises it, and the others are too late to be of any use.

How Dandelions are fertilised.—Dandelions are much visited by Insects, for they are bright-coloured flowers with honey in their corolla-tubes. Flying Insects

bring pollen from distant flowers, and this is best for the Dandelion. If no flying Insects come, the plant manages to fertilise its own seeds. This is not so good as being cross-fertilised, but I suppose it is better for the Dandelion than not being fertilised at all. Some flowers, however, not Dandelion flowers, would rather not be fertilised than be fertilised by their own pollen. The arms of the style curve completely round in flowers which have been opened some days, and the stigmas brush against the anthers, which have by this time burst, and are dusted all over with loose pollen-grains. I have made a little model which will show you how the style and anther-tube act. Here is a small ring about a quarter of an inch across. I have passed through it two curly slips of cane. Now I draw the ring up to the ends of the canes, which close up like the arms of the Dandelion style when the flower is very young. Next I draw the ring down a little, and the canes begin to separate, as they do in the Dandelion when the style begins to lengthen. Lastly, I slip the ring down so far that the inside surfaces of the canes curve completely round, and touch the outside of the ring, in the same way that the stigmas of the Dandelion brush against the outside of the anther-tube when the flower has been long open.

Notice that the outer flowers of a Dandelion head open first, and then the inner ones, in regular order to the centre. All the flowers do not open at once; if they did, the Insects would be puzzled among such a multitude, and very likely some flowers would not get fertilised at all.

What happens after Fertilisation.—After the have received their pollen the corolla withers,

the outer green leaves close, the Dandelion bows its head, and lies close to the earth. It rests in this position for a few days while the seeds ripen. Then it stands up erect once more, the green leaves part, and the flowers, or what is left of them, spread for the last time. How much they have changed! The yellow corolla has fallen off, and carried the stamens and styles with it. The calyx with its brush of silvery hairs is still there, but instead of standing just on the top of the ovary, it is now mounted on a long stalk nearly an inch long, which has been growing all the time that the flowers have been lying shut up. The ovary is no longer white and soft, but brown and firm. The seed inside is now ripe, and ready to be sown. See how lightly it holds on to the top of the flower-stalk. It hangs only by the finest thread, and a puff of air is enough to free it from its base.

Plumed Seeds.—It is easy to see why the calyx is provided with the plume of down, which is now expanded so wide. The wind catches the plume, breaks the seed away from the flower-stalk, and sends it far over the fields. Can any of you tell me why the stalk of the plume, which is really the tube of the calyx, goes on growing longer and longer as the seed ripens? It is to make room for all the plumes which want to expand at the same time. Close to the seeds there is very little room, but an inch away there is room for a hundred plumes to spread at once.

Why Dandelions are so common.—When we consider that the Dandelion is so hardy that it keeps green all the year, and flowers from spring to autumn, that it is protected by its bitter juice from gnawing animals, that each head of flowers produces many seeds, and that these seeds are spread far and wide by the wind, it is not surprising

that it should be so very common, and should stand its ground in the most crowded situations. The Dandelion can turn out most other plants, but there are hardly any which can turn out the Dandelion.

LESSON XLV.

HOW PLANTS SCATTER THEIR SEEDS.

WANTED:—*Pods of Broom (dry)*; model described on page 154; *Pine cone containing seeds*. A case may be fitted up with (1) *Winged seeds*, (2) *Hooked Fruits and Seeds* (e.g. *Cleavers, Agrimony, Burdock*), (3) *Plumed Seeds*, (4) *Imitative Seeds* (e.g. *Castor Oil Seeds*) and (5) *Mechanically ejected Seeds* (e.g. *Pansy, Broom, Geranium*).

Why Plants scatter their Seeds.—We saw the other day how a Pansy scatters its seeds, and I told you why it does so. If several hundred seeds were to fall down close to the parent plant, very few, perhaps not one, would come to full size. They would be overshadowed from the first, and dreadfully crowded together. Many other plants are in the same difficulty, and they have various ways of getting out of it.

Pod of the Broom.—Some plants which produce pods manage to shoot their seeds to a distance by a very simple contrivance. If we examine a pod of the Broom, we shall find that it is made up of two halves or valves, just as in a Pea or Bean. The seeds are fastened along the upper side of the valves, and generally stick to one valve or the other when the pod bursts. This happens only when the seeds

are quite ripe; then the pod dries and cracks, and finally opens into two valves. The seeds are rather heavy, and would fall to the ground at once if some special contrivance were not arranged on purpose to scatter them. This contrivance is found in some strong fibres contained in each valve, and passing across it not by the shortest way from one edge to the other, but in a slanting direction. When the fibres dry, they shorten and pull the valve into a spiral or corkscrew shape, twisting out the seeds, and throwing them one by one to a distance. Here is a bit of stiff paper to which I have fastened some elastic bands just in the same position as the fibres in the valve of the Broom.* At present the elastic bands are kept stretched by a heavy plate of glass laid upon the model. When I lift the glass the bands shorten and pull the edges of the paper nearer together, and you see that it makes a spiral or corkscrew. In the Broom the pull of the fibres is so great that the seeds are nipped hard, and suddenly escape with a force which flings them far away. On a summer day when the sun is shining brightly the pods of the Broom go pop! pop! one after another, and fire off their seeds.

Pine Seeds.—The Pine has a quite different way of scattering its seeds. Here is a Pine-cone, which I will break open. A number of seeds come out, each of which has a long flat plate or wing fastened to it. Now I hold one of the seeds up in the air as high as I can, and let it drop. Or, better still, I put it on the end of this long

* To make such a model as that referred to in the text, cut a piece of stiff paper or thin card, say 15 in. long and 3 in. wide. Mark equal divisions, say inches, along each long side, beginning from the same end. Sew pieces of elastic, 2 inches long, from mark No. 1 on one side to mark No. 2 on the other, and so on.

stick, and raise it up as high as possible, and then shake it off. The seed comes fluttering to the ground, turning round and round all the time.



Fig. 93.—CONE OF PINE.

Do you see how slowly it falls? To make this quite clear I will now hold up two Pine-seeds. One is winged as before, but the other has had the wing cut off. I release both at the same instant, but they will not reach the ground together. One falls straight and fast, but the winged seed loses so much time by fluttering and turning round that it reaches the floor long after the other. The wing on the seed helps to waft it to a distance.

Pine - seeds are usually shaken out of the cone when a high wind is blowing. If the air is still they lie quietly between the scales of the cone and do not fall to the ground at all. When a seed is falling in this slow fashion there is plenty of time for the wind to catch it and blow it far away. The wind can easily bear along a light seed with a broad wing fastened to it.



Fig. 94.

Many other plants have winged seeds like the Pine. The Ash, the Sycamore, the Elm, and the Birch, are

common examples. Notice that all these are trees. Winged seeds would be of no use to a low plant, for they would fall to the ground before the wind had time to carry them any distance. I think that none of



Fig. 95.—WINGED FRUITS OF SYCAMORE.

you can mention a single low plant with winged seeds, though many have plumed seeds.

Hooked Seeds.—Some plants, which are quite low and near the ground, have a different way of scattering their seeds. When we go into a wood in summer to gather flowers we sometimes find ever so many seeds and small fruits clinging to our clothes. Once I had the curiosity to count all that I could find. I counted more than two hundred, and I dare say that there were many more which I did not see. All these had hooks upon

them, little hooks which you can hardly see distinctly, but which catch tight hold of anything rough, especially of stockings or woollen clothes. When you shake or brush your clothes after a ramble, you scatter seeds of many small plants, such as Cleavers, and Forget-me-not, and Agrimony. It is not wandering naturalists, or boys and girls, that these plants are looking out for, but sheep and

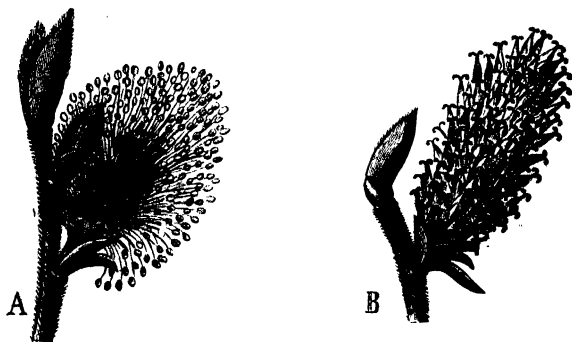


Fig. 96.—A, CATKIN OF WILLOW. B, SPIKE OF PISTIL-BEARING FLOWERS, FROM A DIFFERENT TREE.

cattle. Such animals bring away multitudes of seeds in their wool or hair, and sooner or later many of these seeds find their way to some spot of waste ground far from the place where they were picked up. Hooked seeds and fruits are never found on high trees. They would be as useless there as winged seeds on low plants. Hooked seeds are found on low herbs, and winged seeds on high trees, each in the place that is fittest for it.

Willow Seeds.—The seeds of the Willow are very interesting. In early summer you will find little pods on the Willow, which burst into two halves, and allow the

seeds to escape. But I must tell you that you will not find these pods on all Willow trees. Some Willows bear bunches of stamens called *catkins*, or *palms*, in early spring; these never bear *Pods*, which are carried on different trees. If you find a pod-bearing Willow-tree in May or June you will easily find the seeds. They are covered with fine silky

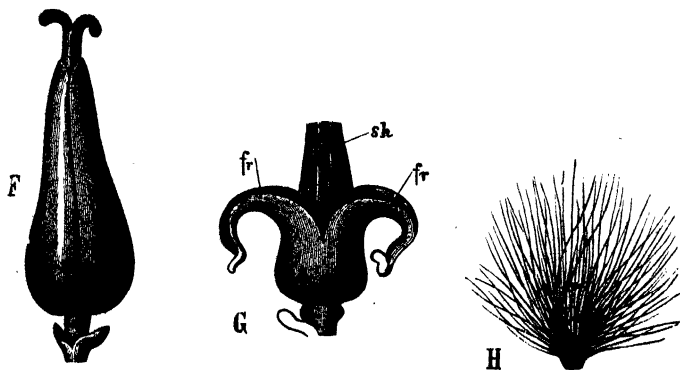


Fig. 97.—F, PISTIL-BEARING FLOWER OF WILLOW. G, POD BURST OPEN (*sh*, seed-hairs; *fr*, ovary). H, HAIRY SEED.
(All are magnified.)

hairs, which stand out in all directions. So long as they are packed in the pod they lie quite close, but when the pod bursts open, air gets in, the hairs dry, and then they try to spread out. If you take a little pinch of the seeds, and lay them on a sheet of paper, you can watch the hairs opening and pushing the seeds apart, and in a few minutes the little packet of seeds has swelled out into a large fluffy mass as light as down, and ready to be blown far away by the first puff of wind. A Bulrush in autumn will show the same thing, if you take a pinch of the seeds from the dark brown spike at the top of the reed. Willow-herb is

another example. The pod of the Willow-herb bursts into four valves, and a mass of cottony seeds appears between them, which swells into a large and very light downy cloud as the hairs dry.

Plumed Seeds.—Dandelions, and other plants like Dandelions, have beautiful plumes on the seed. Thistle-seeds cling together by their plumes, and form a downy mass like that of the Willow or Bulrush. All these plants have their seeds blown far and wide by the wind.

Seeds which imitate Animals.—Some seeds and fruits look very like small animals, such as Spiders, Caterpillars, or Beetles. They are probably mistaken for objects of this sort by Insect-eating Birds, and carried off. When the Bird finds out its mistake, it drops the seed, but by this time the seed has been carried away from the parent plant, and that is all that is necessary.

Eatable Fruits.—You know that many seeds are enclosed in eatable fruits. Such fruits are much eaten by Birds, especially by Thrushes and Finches. The fruit is generally carried off, and after the eatable part is swallowed, the hard seeds are dropped. Some soft fruits, like Plums and Cherries, have hard shells to protect the seed, lest it should be swallowed and dissolved in the Bird's stomach.

Other contrivances for scattering Seeds.—But there is no end to the contrivances by which seeds and fruits are scattered. There are sticky seeds, which are carried off by Birds in their feathers, and lodged after a long time in places where they can spring up and flourish; there are floating seeds like the Cocoa-nut, which can be tossed for weeks on the waves of the sea without being injured; there are plants which bury their seeds in the earth, and plants which bury their seeds in the crevices of a wall, and

seeds which are able to bury themselves. There are seeds which are carried off by Birds and then dropped because



Fig. 98.—ROSE OF JERICHO.

In the upper figure the plant is shown curled up; in the lower figure it is expanded.

they are hairy or ill-tasted. There are seeds which are squirted out by the ripe fruit. There are plants, like the Rose of Jericho, which curl themselves up, leaves and root and all, during long droughts, and let themselves be

blown about by the wind, but revive, and take root and flower, and set their seeds, as soon as they reach water or are wetted by rain. The more you know of plants the more you will wonder at the beauty and variety of the

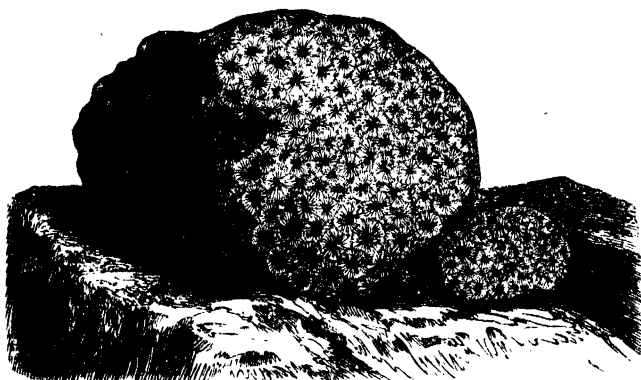


Fig. 99.—ONE OF THE CORALS WHICH FORM REEFS.

contrivances by which they are saved from dangers, and helped to do their work.

How Plants are carried to Coral Islands.—You have heard of the coral islands of the Pacific and Indian Oceans. These are formed of white coral built up by little polyps, which live in the sea. The coral never forms above the surface of the sea, because the coral polyps perish when they are exposed to the air. Some of the coral islands now stand high up out of the sea, and contain mountains several hundred feet high. They must have been formed beneath the waves, and afterwards raised until they became dry land. Upon some of these coral islands, hundreds of miles from the nearest continent, many plants are found,

and these show how far seeds may be carried. Some of the plants have sprung from plumed seeds borne by the wind; some have sprung from seeds and fruits which have been carried by currents in the ocean. The Cocoa-nut will live a long time in salt water, and Cocoa-nut Palms are commonly found on coral islands. Other seeds are carried in the crops of grain-eating Birds. Others are sticky or prickly, and have been known to cling to the plumage of Herons and other water-Birds. A Heron, blown far out to sea by a gale of wind, might carry such seeds to a coral island, and we know of one case where this has probably happened. Birds sometimes get a little earth on their feet from walking about in muddy places, and this earth generally contains small seeds. Insects and other flying animals now and then carry small seeds. In one way or another the coral island is soon stocked with plants, though the number of kinds will be small.

How Plants spread to new-made Ground.—When a field is ploughed up, or a new railway embankment made, we see that it is soon covered with plants. The soil contained many seeds to begin with, if it was surface-soil. During the first summer great numbers of plumed seeds are wafted by the wind, and other kinds of seeds are dropped by Birds. The annual weeds, which last only for one season, spring up in great numbers, and sow their seeds all around. But the slow perennial plants, which last several seasons, come in at last, and these generally drive out the others. Perennial grasses which form turf, and small shrubs and plants with large roots going deep into the earth, and storing up food for the next year, slowly establish themselves, and occupy all the more fertile spots. Before long there are no bare places left, and all the

ground is as thickly covered with plants as if it had never been disturbed.

Many Seedlings perish early.—There is a great destruction of seedlings (very young plants) always going on, and that is why so many are produced. Mr. Darwin cleared a bit of ground, three feet long and two broad, and marked all the seedlings which came up. 357 were counted, but out of these 295 were destroyed, mostly by Slugs and Insects. Another time he took three table-spoonfuls of mud from the edge of a little pond, and kept the mud covered up in his study for six months, pulling up and counting each plant which came up. The plants were of many kinds, and there were 537 altogether. Very few of these plants would ever have sprouted if they had been left where they were found. All over the surface of the ground are vast numbers of seeds and seedlings which only want light and a little free space to grow up into strong plants.

LESSON XV.

HOW PLANTS DEFEND THEMSELVES FROM THEIR ENEMIES.

WANTED :—*A Thistle in flower, and beginning to seed.*

Enemies and Friends of the Thistle, and how it deals with them.—Look at this prickly Thistle. The edges of the leaves run out into stiff points, some turned one way, and some another. There are larger prickles, which are stout enough to resist a strong animal, and there are smaller points between to stop small animals which might creep between the large prickles. The stem is armed in the same fashion, and round the flower-heads are more points, which are generally turned down. Few creatures would venture to attack a Thistle. Cattle turn aside from it; soft-bodied Snails are obliged to keep off, and even hard-bodied Insects lose much time among the prickles, though they do not allow themselves to be pricked. The Ass is almost the only animal that can get any good out of a Thistle. You know how quickly Thistles spread, and how hard they are to get rid of. This is partly owing to their plumed seeds, which are blown about everywhere by the wind, partly to the points and prickles, which keep off all kinds of gnawing and browsing animals. The Thistle says to them, "If you bite me, I will prick you," and it keeps its word. Flying Insects, which only come to sip the sweet juice of the flower, are not molested at all. The Thistle wants their help: it depends upon them to carry its pollen from flower to flower. So it attracts them by showing a mass of purple flowers, easily seen a long way

off, and it fills the tube of each of its flowers with honey, and it plants no thorns where they might prick such visitors as these. Instead of thorns, there is a soft fragrant cushion for them to rest on, and Moths and Bees and Flies and Beetles find themselves so comfortable in Thistle-flowers that they often go to sleep there. Night comes on, and the flowers close to keep out the wet and cold, but the Insects sleep on undisturbed. Hardly any plant is so popular with large flying Insects as our common Field Thistle, a tall plant with many rather small heads of purple flowers. But creeping Insects which cannot fly are kept at



Fig 100. - FIELD THISTLE.

a distance. They would be of no use to the Thistle, and they would eat up the good things without making any return, besides molesting more profitable guests. The Thistle does all it can to shut them out.

Ants mischievous to many Flowers.—Ants appear to be a great plague to all the flowers which keep honey as a bait for flying Insects. Ants are extremely fond of honey, and are very clever at finding it out. But they can do no good to the flower. When they get dusted with pollen they do not go straight off to another flower and leave it on the stigma, as the Bee would do, but they ramble about

looking for something to eat. Even if they knew the way, and went as straight as they could, it would take them a long time to reach the next plant of the same kind, for they would have to run over the ground all the way, and brush against countless blades of grass and little twigs. The Ants would be much more likely to eat the pollen than to fertilise flowers with it.

Ants kept off by Hairs.—Many plants have special defences against Ants, and some of these are very curious. One of the commonest and most successful means of keeping them off is by hairs. Some plants have their leaves and stems covered with long weak hairs, which get felted together. The Ants get their hooked feet fast in the felt, and cannot move a step farther. Sometimes the hairs are long and stiff, and point outwards, making a circle round the stem like a railing, so that the Ants cannot get past. A circle of stiff hairs close together keeps Ants out better than the prickles of the Thistle. You can see Ants creeping about the Thistle, though slowly and with difficulty, but they are completely stopped by a circle of hairs so small that you cannot see it without looking very closely.

Plants with sticky Hairs.—In many plants the hairs on the stem, or the outside of the flower, are tipped with little balls of gum, and this baffles Ants and other creeping Insects entirely. They are not only prevented from going any farther, but they are often glued fast and never get away at all. Here is a London Pride in flower. Look very carefully at the flower-stems. You will see a great number of small hairs standing out on all sides. Each hair is tipped with gum, and many creeping Insects are held by the gum until they die. The London Pride is a *Saxifrage*,

and many other Saxifrages defend themselves in the same way—that is, by means of sticky hairs. You will see them very well if you look at the outside of the calyx with a magnifying glass.

Hairs of Grasses.—Some Grasses have their leaves so closely covered with hairs that a drop of rain will not wet them, but rolls off to the ground. These hairy grasses are



Fig. 101.—COROLLA OF SNAP-
DRAGON.

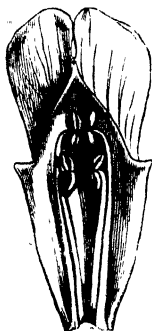


Fig. 102.—COROLLA OF SNAP-
DRAGON OPENED.

disliked by cattle. I believe that the leaves cling to the tongue and stick in the throat. You may often see a great tuft of hairy grass left untouched in a pasture, while all the grass around is cropped close.

Snapdragon.—The Snapdragon closes its large flowers so tightly that small creeping Insects cannot get into the corolla. But the Humble-bee is strong enough to push the corolla open, and get at the sweets inside. The Humble-bee must be encouraged, because he is useful in carrying pollen from flower to flower.

Poisonous Plants.—Some plants are poisonous, and are let alone by animals for this reason. Others have a bitter juice, and some have a perfume which is unpleasant to Insects.

Milky Juices.—Dandelions and Poppies and Spurges send out plenty of milky juice when they are wounded. I think that this juice is disagreeable to gnawing Insects. The German naturalist, Kerner, once placed some Ants upon Lettuce-plants to see what would happen. The Lettuce contains milky juice like the Dandelion. No sooner had the Ants reached the upper leaves, or flower-stalks of the Lettuce, than the sharp hooks on their feet cut through the skin of the plant and the milky juice began to flow. The Ants were soon daubed over with juice, which hardened into a tough brown glue on exposure to the air. The more the Ants struggled the worse they were off, for every wound caused more juice to flow. Some bit the leaves in their rage, and got their jaws clogged. A few were sensible enough to let themselves fall from the leaves to the ground, but those which persevered got more and more entangled, and were at last left dead or dying on the plant.

Insect-eating Plants—the Teasel.—There is still one curious fact to mention. A few plants not only prevent Insects from gnawing or injuring them, and imprison or kill those which are too obstinate, but they actually digest their dead bodies. Mr. Francis Darwin found that the Teasel is one of these Insect-eating plants. The leaves on the stem are placed exactly opposite to each other; they are wide at the base and joined together in pairs, so as to make a cup through which the stem passes. Rain-water collects in the cup, and forms a moat round the stem.

Creeping Insects trying to make their way through the water are drowned in it, and their dead bodies soak till they form a sort of thin soup. This soup is used by the Teasel for food. It sends out a number of slender filaments into the cup, which drink up the fluid, and so the plant extracts all the nourishing part of the bodies of its enemies.

The stem of the Teasel is rough with small prickles, and round the flowers is a circle of stiff, pointed and prickly leaves. Besides, long spines stand out between all the flowers, which are gathered together into a close head. I think that there are few plants so well protected as the Teasel. When the seeds are ready to be carried off, the prickly points are very easily entangled in the fleeces of sheep, and get carried to a distance in this manner. The dried heads of this plant have long been used to *tease* woven cloth, that is, to scratch up the surface and raise the hairs. It is called *Teasel* on this account.



Fig. 103.—COMMON TEASEL.

The Butterwort.—There is a plant known as the Butterwort, which grows in bogs and on wet rocks in hilly districts, and this is also able to capture and digest small Insects. The Butterwort forms a rosette of about eight thick yellowish leaves, which have a glistening surface and a clammy feel. The flowers are purple, and carried on

long stalks. The edges of the leaves, especially of the old leaves, are often folded inwards over the upper surface. Our great naturalist, Charles Darwin, studied the Butterwort very carefully. He found that if small Insects or bits of Flies are placed on the edge of a young leaf, the leaf folds over them and encloses them. The glands of the leaf, which are set closely over its upper surface, and give it a glistening appearance, then pour forth a fluid, which after a time is found to turn acid, and to dissolve the soft parts of the Insect, in the same way that the acid fluid of the stomach dissolves pieces of meat. After a time all the nourishing substance of the Insects is dissolved out, and drunk up by the leaves. Bits of raw meat were found to set up an abundant flow of acid juice, which slowly softened them and made them transparent. Small cubes of boiled white of egg could be entirely dissolved.

In Switzerland and other mountainous countries it has long been known that the leaves of the Butterwort are acid and will curdle milk. Fresh leaves are boiled in milk to thicken it and make a sort of curd. The plant is called *Butterwort* for this reason.

Experiment.—Where fresh plants of the Butterwort can be procured, the following experiment may be tried. Get a little book of litmus paper, which is dyed blue by a colour obtained from a plant. This paper turns red when wetted by weak acids. Press a fresh leaf of the Butterwort, which has collected no Insects, upon the paper. The colour remains unaltered. Press a leaf upon the paper in the same way while it is in the act of digesting a Fly or a small bit of meat; the juice poured out around the Fly or bit of meat turns the paper red, and is thus shown to be acid. Look out for Insects captured by the plant, and

also try to thicken milk with the leaves. When the plant is pulled out of the ground the leaves curl backwards towards the root. This inclination to curl backwards keeps the rosette tight against the ground, and prevents other plants from interfering with it.

The Sun-dew.—The most interesting of our native Insect-eating plants is the Sun-dew, which was also admirably described by Charles Darwin. This is found in boggy places, on moors, and wide commons, and can be found with a little trouble in most parts of the British Islands. It is rather hard to see the plant, even when there is a great deal of it about, for the reddish leaves look very like some kinds of moss which grow in wet ground. When the plant has once been found it is generally easy to get plenty more.

We have three kinds of Sun-dew. In the Common Sun-dew the leaves are shaped like salt-spoons, with long stalks and rounded ends, and a number of such leaves make a rosette. The other two kinds have longer leaves, which stand up instead of forming a flat rosette on the ground. All our Sun-dews have clusters of small whitish flowers on long stalks. The bowl of the spoon-shaped leaves is stuck all over with large hairs or tentacles, which become longer



Fig. 104.—BUTTERWORT.

Small captured flies are seen on the leaves.

and longer the nearer they are to the edge of the leaf. Each of these tentacles has a small gland on the tip, and every gland distils a large drop of sticky fluid, which

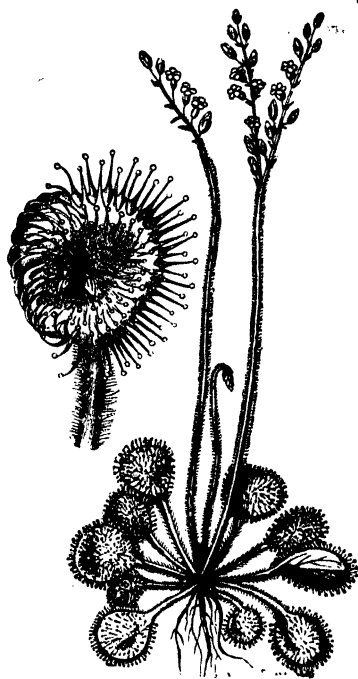


Fig. 105.—COMMON SUNDEW, WITH A LEAF (MAGNIFIED).

The tentacles on the leaf are closing round a small fly.

glitters in the sun like a drop of dew, and suggested the name of *Sun-dew*, by which these plants are known.

How the Sun-dew catches Flies.—If a small Fly happens to touch one of the tentacles, it is caught by the sticky fluid. The tentacle bends slowly inwards towards

the middle of the leaf, and every tentacle which is touched by the struggling Insect bends too. The impulse to bend is given also to tentacles which have not been touched at all. The glands soon pour forth more fluid, and this becomes acid, as in the Butterwort. Before many minutes have passed the Insect ceases to struggle. Now the tables



Fig. 106.—LEAF OF PITCHER-PLANT.

are turned, and the Sun-dew begins to eat up its enemy. The tentacles close over the dead body, and the acid juice acts upon it until all the soft parts are digested. After two or three days the tentacles open out again and wait for a new victim. Bits of meat or boiled white of egg are digested as easily as the muscles of a Fly if they are quite small. If substances useless for food are dropped or blown upon the leaves, the plant closes its tentacles for a time, but soon finds out its mistake and releases them.

Experiment.—Test the fluid of a fresh Sun-dew's

tentacles with litmus paper. The leaf must not have captured Insects, or have been excited in any way. No visible sign of an acid will be detected. Put small cubes of boiled white of egg, about one-twentieth of an inch in diameter,



Fig. 107.—FLY-TRAP OF NORTH CAROLINA.

upon the same leaves. Observe the closing of the tentacles. After twenty-four hours test again for acid, when the litmus paper will be found to turn red wherever the fluid touches it.

On a wet, boggy moor the Butterwort or the Sun-dew must be very glad of an occasional meal of animal food, for they can hardly draw up anything but water through their roots.

Other Insect-eating Plants.—There are many other kinds of Insect-eating plants, such as the Pitcher-plants of the East Indies, which entice Insects into their great water-pots, and the Fly-trap of North Carolina, which folds up and imprisons them between the halves of the leaf. But it will be best to tell you only about those which you can gather and observe for yourselves.

LESSON XVI.

CHRISTMAS DESSERT.

WANTED :—*Oranges, Walnuts, Raisins, Almonds, Figs.*

Oranges.—Would you like to know something about the fruit on the table? You see that we have Oranges, Walnuts, Raisins, Almonds, and Figs, before us. I will tell you a few things about Oranges to begin with.

Where do Oranges come from? From many warm countries—from Sicily, Spain, the Azores, Florida, California, and of late years from Australia. They are grown in many other parts of the world besides which do not send fruit to us.

Oranges have been much improved by cultivation. There seems to be no country where wild Oranges are to be found so large and well flavoured as those which we are accustomed to see. But there are wild Orange-trees in the jungles of some parts of India, and these may perhaps be the wild stock from which all our cultivated Oranges have been got. In Burmah and China too are wild Orange-trees which may turn out to be the original kind. Orange-trees have been cultivated in India, China, and Japan, for

hundreds, and perhaps thousands of years. They were first brought to the countries on the Mediterranean Sea by the Arabs, and afterwards they were taken to France and Italy by the merchants of Genoa and others. The

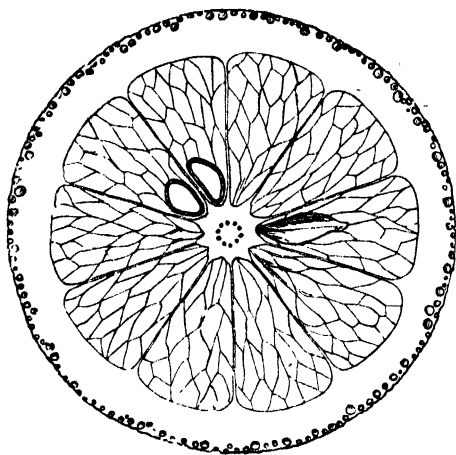


Fig. 108.—SECTION OF AN ORANGE.

Portuguese brought Oranges from China to their own country and to the Azores.

Have you ever seen an Orange-tree? It has glossy evergreen leaves of peculiar shape. The stalk widens out as if it formed part of the leaf, but there is a clean line of separation running across where the proper leaf begins. The flowers are white, or pale pink in some sorts. The fruit hangs long upon the tree, so that you may see last year's fruit and this year's flowers side by side. When the flowering season is over, the style falls off, and the ovary enlarges till it forms the fruit. You can see a very small

scar on an Orange, where the style once grew, and a much larger scar at the other side where the fruit was fastened to the stalk. One large tree will often bear a thousand Oranges at once.

The outer part of the rind of the Orange is full of little cavities which contain a strong-scented oil. This oil can be dissolved out by alcohol, and is used in the manufacture of Eau-de-Cologne. - Then we come to a white rind, and in the middle of the fruit are a number of carpels, or divisions of the ovary, each filled with pulp, and generally enclosing a single pip or seed. The pulp contains a good deal of acid, and, when quite ripe, sugar too.

Seville Oranges have a bitter taste. Marmalade is made from the fruit, and Orange-water from the flowers.

Lemons are a kind of Orange with much acid in the pulp. They can generally be told by the shape of the fruit, which is oval, and has a knob at the end where the style grew.

Citrons are a kind of large Lemon with a thick rind, which is often preserved in sugar.

Limes are Oranges with a very acid fruit, which can hardly be eaten by itself. A little of the juice, squeezed into water and sweetened, makes a refreshing summer drink.

Bergamots are small, pear-shaped Oranges, with a delightful perfume.

Shaddocks are large round Oranges with a very thick rind.

You see that Oranges, like all plants upon which much pains have been bestowed, have been much improved by cultivation and selection, and have broken up into different

kinds. At the present time we do not know for certain whether they were all alike at first, or whether they have sprung from several wild sorts.

If you plant an Orange-pip in a flower-pot, and take care of it, the seedling will open its leaves, and grow into an Orange-tree. Sometimes there are two, three, or four seedlings in one pip.

Very little is known about wild Oranges, and I cannot tell you for certain why they have pulpy fruit and strong-scented oil in the rind. But I fancy that the pulpy fruit tempts Birds to scatter the pips, and that the oil keeps them from tearing open the fruit until the seeds are quite ripe. The strong scent of the flowers and leaves is a protection against gnawing animals, and may attract flying Insects to visit and fertilise the flowers.

Walnuts.—Walnuts grow upon good-sized trees which are often to be seen in England, though they are not native to this country. They come from the temperate parts of Asia, between Russia and Japan. The Walnut-tree has large, fragrant leaves. The wood is dark brown, and beautifully marked. It is hard, and takes a good polish, so that it is much fancied for gun-stocks and cabinet work. The fruit of the Walnut is at first covered with a green rind, which is very bitter. If you get the juice of this rind on your hands or face it turns the skin brown or black. Inside the green rind are two carpels, or divisions of the ovary. Each carpel is a hard shell, and the two shells fit together and make a nut. We should expect to find at least two seeds inside the two carpels, but only one ever comes to full size. So we have two carpels enclosing one large seed, and outside the carpels is the green rind, which is formed of the hollowed-out end of the flower-stalk.

If you look carefully at a Walnut, you will see that it is flatter at one end than the other. The flat end has a scar which shows where the carpels grew out of the flower-stalk. At this point the seed was joined to the carpels, and here it received the nourishing fluids which enabled it to grow big.

The space inside the two carpels is divided in four by four imperfect partitions. Hammer the shell of a Walnut gently, and break it away little by little till you can see the seed entire and the four corky partitions. The seed is crumpled into a very uncommon shape, and it is completely covered by a thin brown skin.

What do we find inside the brown skin? A young Walnut-tree. This is a surprise, for the white stuff inside the skin, which we are accustomed to eat, does not look much like a Walnut-tree, nor indeed like any sort of plant. But I tell you the exact truth. When we eat a Walnut, we eat a young Walnut-tree, and, as nearly as possible, nothing whatever else. The root of the young plant is pointed and turns up towards the pointed end of the shell. You can easily see it for yourselves. The stem turns downwards and is very small, but with careful dissection even the minute leaves and buds upon it can be seen. The rest of the young plant within the shell is made up of a pair of large, crumpled, fleshy leaves, each folded along its length, with a corky partition in the hollow and a pair of partitions between the two leaves. These seed-leaves, as they are called, contain much oil. Where Walnuts are plentiful, many nuts are collected and taken out of the shell, and squeezed by machinery to press out the oil, which is used for mixing paints and varnishes.

If you plant a Walnut in damp earth, the rind and

shell slowly decay. Then the seed begins to swell, and pushes out a slender white sprout, which is the root. The root lengthens and fixes itself in the earth. After a time the stalk comes out, but the seed-leaves never come out at all. Their oil is used as food by the growing plant, and when all the oil has been drunk up, nothing is left but a withered husk, which is left to rot in the rotten shell. But the stem goes on pushing upwards through the earth, and when it reaches the open air it unfolds its leaves, which soon turn green. The first leaves are very small, but in a few years the young tree puts forth leaves like those of the parent.

Well-grown Walnut-trees are very useful. The young fruit is made into pickles, the ripe fruit is a pleasant dessert, and the wood is much valued. But it is not often planted, because great boughs are very apt to break off, and then the tree takes an ugly shape. Besides this defect, the stem often decays, and becomes hollow, so that people who make a point of having shapely trees in their parks and plantations do not plant Walnuts.

Why is the rind of Walnuts bitter? I suppose it is to prevent Quadrupeds, Birds, and Insects from munching them up. Why have they a hard shell? No doubt for the same reason, as a defence against animals. There is a thin-shelled variety of the Walnut, which suffers from the attacks of Tom-tits. How does the Walnut scatter its seeds? I cannot tell you, for the Walnut does not grow wild in any country that I have seen, and we must study trees in their native haunts to understand their wants, and how their wants are met.

Raisins.—Raisins are dried grapes, and grapes are the fruit of the Vine. Raisins are dried in various ways. Sometimes they are merely left on the Vine till ready. In

other places the stalk is cut nearly through to hasten the drying. When a soft glossy skin is desired, the clusters are dipped into boiling water before drying.

Malaga Raisins, such as are used for dessert, are carefully picked and dried in clusters. They come from Malaga, Valencia, and Alicante, in Spain. Smyrna sends us large cooking Raisins, as well as a small kind without seed, known as Sultanas. The Ionian Islands grow small grapes, which are gathered and laid in the sun in drying grounds, and turned over continually till they are made into a kind of Raisins, called Currants. Notice that these Currants, which are sold by the grocer, have nothing to do with the Black and Red Currants grown in our gardens, which are so called only because they are of the same size and appearance as the others.

All these kinds of grapes, as well as many others which are used for making wine, come from one wild stock. Few cultivated plants have branched out into so many different varieties as the Vine.

Perhaps you wonder how seedless grapes can continue to live year after year. They could only live when cared for by man, for they must be multiplied by cuttings. Shoots are cut off from the old plants and set in the earth, or grafted upon other Vines, and with proper care they grow into fruit-bearing branches.

Raisins contain much sugar, and also a sour substance called *cream of tartar*.

Almonds.—Almonds are the kernels of a fruit-tree very like a Peach. But the fruit is not soft and eatable, like that of the Peach, it is tough and dry. The kernel is the only useful part.

The Almond is a native of Syria and some neighbouring

parts. Most of the fruit comes to us from Spain and the Mediterranean countries. The tree is common in English gardens, but never ripens its fruit in this cold climate. The flowers are pink, and appear in early spring before the leaves. An Almond-tree in blossom is a beautiful sight.

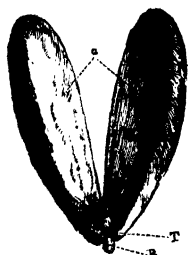


Fig. 109. — ALMOND
REMOVED FROM THE
HUSK AND OPENED.

a, Seed-leaves; T, young
stem; R, young root.

Besides the dessert Almond there is a variety called the Bitter Almond, which contains a strong-scented, poisonous oil, which is used very sparingly in cookery.

You can easily split an Almond into halves. The halves are the seed-leaves, which are filled with oily food for the nourishment of the young seedling. At one end you will see a small pointed rod lying between the two seed-leaves. This is the future stem and root. When the seed sprouts, the oily substance is used up as food, and before long, green leaves push out from the stem. After that the plant finds food for itself.

Figs.—Figs come from the Mediterranean, especially from Smyrna. They are borne upon small trees with broad, deeply lobed leaves.

The eatable part is the end of the flower-stalk, which swells and grows fleshy, and turns inwards at the edges to form a pear-shaped cup. All the flowers are inside. Near the mouth of the cup are a few flowers which bear stamens but no pistil. Further in are very many flowers which bear pistils, but no stamens. It is necessary to have the pollen brought from the staminate to the pistillate flowers, and this is done by Bee-like Insects, which creep into the hollow

flower-stalk, and fertilise the flowers. When a pistillate flower ripens, it produces only a single seed, so that there is a flower for every one of the countless seeds inside a Fig, and a few staminate flowers besides. It seems that too little pollen is produced by the cultivated Figs, or else too little is carried to the pistillate flowers, for it is found that many Figs drop off early because they have not been fertilised. This is prevented by placing flowering branches of the wild Fig in the cultivated trees. The ripe Figs are gathered, dried in the sun, and packed up for sale. They contain much sugar.

If you plant Orange-pips, or Walnuts, or Shell Almonds, and keep them warm and well watered, they will generally grow. But I believe that Raisins and Figs will hardly ever produce Vines or Fig-trees. Even in the countries where they grow out of doors they are never raised from seed, but always by cuttings.

Different parts eaten.—You see that different parts of different plants are eaten as fruit. In the Almond and Walnut we eat the seed. In the Orange and Raisin we eat the pulp between the seed and the outer rind. In the Fig we eat the fleshy top of the flower-stalk, as we do in the Apple and Pear also.

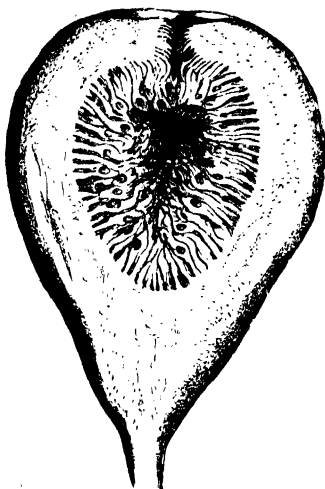


Fig. 110.—UNRIPE FIG, CUT OPEN.

Names of Fruits.—The names of these fruits have a history which may interest you. What does Orange mean? Most people used to think that it had something to do with *Or*, which is the French word for *Gold*, or with the Italian and the Spanish *Oro*, which means the same thing. But it appears that we get the word from the Arabs, who called the Orange *Narunj*. The Italians got hold of this name, and turned it into *Naranzi* and afterwards into *Arangi*. So you see *Orange* should by rights be *Narange*.

Wal in Walnut means *foreign*. We have the same word in *Wales* (which originally meant “foreigners”), *Walloon*, and some other words.

Raisin is a French word, altered from the Latin *racemus*, which means a bunch of grapes.

Currants are named from Corinth, where they used to come from.

Almond comes to us from the French. The French got the word from the Latin, and the Latin from the Greek.

Fig comes from the French *figue*, and Latin *ficus*.

By the way, we have forgotten the word *Dessert* itself. What does it mean? It is a French word, which means “cleared away.” The Dessert consists of fruit and sweet-meats and other things brought in as soon as the cloth is taken off.

LESSON XVII.

HEAT.

The apparatus required for these experiments on Heat is sufficiently described in the Lesson. It is desirable, and even necessary, that the teacher should have at least an elementary practical knowledge of the subject, such as would be acquired in a short laboratory attendance. Some of the experiments may go seriously wrong in hands altogether inexperienced.

This Lesson will require at least two hours. It will be found convenient to divide it into two parts, and to begin the second part with a short recapitulation of what has already been gone over.

Expansion of Solids.—I have here a flat bar of copper twenty inches long.* I lay its ends on these square blocks of wood. It is necessary to prevent one end of the bar from moving outwards, so I hammer a couple of tacks into the top of one of the blocks to make a stop. The other end can move freely. Now I take a large pin, and pass it through this long and thin piece of card. The card is meant to be a pointer. I lay the pin underneath and across the free end of the copper bar. The bar rests upon the pin, and you see that when I push the bar gently along in the direction of the pin, it makes the pin turn round, and the card pointer turns with it. Then I push the bar back into its place, and make its end rest against the stop. Now we are ready for our experiment, which is this: I put a lighted spirit-lamp beneath the centre of the bar, which

* Twenty inches of the copper tape used for lightning conductors will do very well.

soon grows hot. As it is heated it lengthens a little, so little that we could not see it lengthen without some such contrivance as I am using. When it lengthens, the ends try to move apart. But one end is stopped by the tacks, so that only the other end, which rests on the pin, is free to move. As it moves, the pin turns round, and the pointer with it. At first the pointer stood upright; now it slopes; in a minute it will be nearly level. The

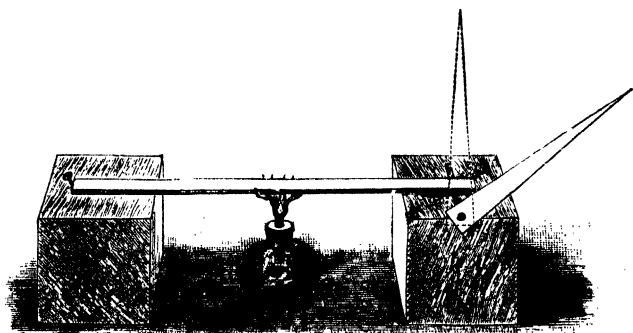


Fig. 111.—EXPERIMENT ON EXPANSION OF SOLID BAR.

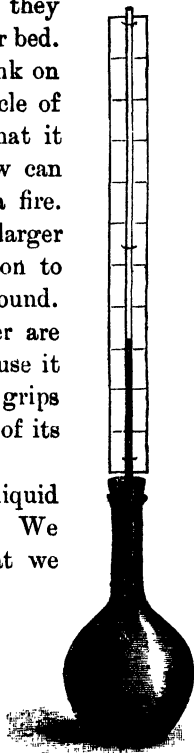
movement of the pointer enables all of us to see that the bar lengthens a little when heated. It not only lengthens, but it becomes broader also, though this could not be made clear without more exact measurement than we can use. To put it shortly, *Copper expands when heated*—that is, it swells, and takes up more room. Very nearly all solid substances do the same thing.

Whenever you look at a railway line, you will be reminded of the expansion of solids by heat. The joints of the rails are not quite close, but a small space is purposely left, so that each rail can expand when warmed by the sun,

and contract again when cooled. In winter the spaces are wider than in summer, because the rails are a little shorter. If the rails touched each other all the way along, they would bend sideways or upwards when they expanded, and tear themselves out of their bed.

Have you ever seen the iron tire shrunk on to a wheel? It is bent round into a circle of the right size, and made to fit so tight that it will never slip off afterwards. But how can it be got on? The tire is heated in a fire. Then it expands, and makes a rather larger ring than before. This is easily slipped on to the wooden wheel as it lies on the ground. When it is in its place, buckets of water are poured upon the tire, which cool it and cause it to contract. The ring gets smaller, and grips the wheel so tightly that there is no fear of its slipping off again.

Expansion of Liquids.—Would a liquid expand in the same way when heated? We must try to find out. You will see that we must fit up a new experiment altogether. The pin and pointer will not do this time. I have here a glass flask filled with coloured water. A cork is fitted into the neck of the flask, and through the cork passes a long upright glass tube, behind which a long strip of paper is fastened. The coloured water rises a little way into the tube,* and I will mark its



112.—EXPANSION OF LIQUID.

* This is arranged by filling the flask quite full of coloured water. When the cork is inserted, the fluid rises a short distance into the tube.

level on the paper. There is a pan of hot water on the table, and I will plunge the flask into it. If heat expands water, the water will rise in the tube. Now all is ready. I lower the flask into the hot water. The coloured fluid *sinks*. That is unexpected! But in a few seconds it begins to rise again; now it has risen higher than it stood at first, and it goes on steadily rising until it has reached a point much above our first mark. I make a second mark at its present level, and lift the flask out of the hot water.

What does this experiment prove? *That water expands when heated.* Then why did it sink at first? Try to find out for yourselves. If you cannot manage that, I will tell you. The *flask* became heated first, and expanded. Then, of course, it became able to hold more water, and the coloured water sank into it. A few seconds afterwards the *water* began to expand, and then it soon rose in the tube. Our experiment really proves that *both the glass and the water expand when heated, but the water more than the glass.*

Why is a narrow tube wanted to show the rise of the water? Because it makes a small amount of expansion easily seen. Perhaps you will not understand this at first. If I were to add a teaspoonful of water to the flask when half full, it would not be easy to see any difference in the height, but if I poured it into a narrow tube, it would cause the level to rise perhaps an inch or two. For the same reason a slight expansion of the coloured water would not be seen in the flask, but it is easily seen in the tube.

All other liquids expand when heated. But I take it for granted that the experiment is made when they are at a moderate degree of warmth. Water, when nearly

enough to freeze, contracts with heat and expands with cold, but if you go on heating it, you will soon see it expand as usual.

Thermometer.—The expansion of liquids by heat is made use of to get an instrument for measuring degrees of heat. Such an instrument is called a *Thermometer*. I have one here. You see the bulb of thin glass, filled with a metal called *Mercury* or *Quicksilver*. Out of the bulb rises a thin tube, which is attached to a scale, on which degrees are marked. When the mercury in the bulb is warmed it expands, and rises in the tube, and the scale tells us how much it rises. But does not the glass expand as well as the mercury? If both expand, why does the mercury rise in the glass tube? It is quite true that the glass expands as well as the mercury, but it does not expand nearly so much. The thermometer really marks, not the expansion of the mercury, but the difference between the expansion of mercury and the expansion of the glass, and that does nearly as well.

Expansion of Gases.—Do gases expand with heat as well as solids and liquids? Let us try. We must think of a handy way of making the experiment. I will use the glass flask with its long tube. First I take out the cork and tube, and empty out all the coloured water. Then I get a short length of coloured water into the top of the tube. This is easily done. I hold the flask in my hand, with the cork and



Fig. 113.—AIR THERMOMETER.

tube fixed in it once more. I turn the whole thing upside down, and dip the end of the tube into the coloured water. Then I remove my hand for a moment from the flask, which is now held only by the tube. The coloured water rises in the tube, but I soon stop it by taking the flask into my hand again. Now I set the flask on the table, and you see that there is a length of coloured water near the top of the tube, easily seen, especially when I put a sheet of white paper behind it. That length of coloured water will serve instead of a pointer. You will find that when I take the flask into my hand, the fluid rises; when I take my hand away, it sinks again. A little ice-cold water makes it sink much further. We may call this simple piece of apparatus an *Air Thermometer*. *The air thermometer proves that air expands when heated, and contracts when cooled*, and it does so much more than water would.*

See the effect of heating air over a flame. I fit a bent tube by means of a cork to a clean dry flask, and let the end of the tube dip into the water in a glass beaker. When I hold a flame under the flask, the air expands and forces its way out, and bubbles up through the water. You see how much air is driven out by a moderate degree of heat. I will hold a beaker over the bubbles of air, and collect them as they rise.

Now I have driven out a good deal of air, and the flask

* A very narrow tube answers best. If it is too wide, the column of water will gradually escape by running down the sides. A more convenient form of Air Thermometer is made by filling the corked flask one-third full of coloured water, and letting the tube dip into the water. The imprisoned air expands when heated, presses upon the surface of the water, and forces it up the tube. The water expands so much less than the air that its expansion may be neglected in rough experiments.

begins to get hot. I will take away the flame and let the air in the flask cool. By-and-by I will plunge the end of the tube into the water again. What will happen? The air will contract. Then the water will rise in the tube and fill part of the flask. If I were not careful to begin when the flask is only moderately hot, the cold water would make the glass fly as soon as it touched it.

It was in this way that I got a little coloured water drawn up into the tube a few minutes ago. I first warmed the flask with my hand. Then I took my hand away, and the flask began to cool. As it cooled, the air inside contracted, and when I dipped the end of the tube into the coloured water, some of the water was immediately sucked up.

Pressure of the Air.—Why was the water sucked up? You remember that a quantity of air was imprisoned in the flask. This air was prevented from escaping by the column of water, and by the air pressing upon the column from the other side. There is a thick layer of air pressing upon the surface of the earth, and this air has weight, though not much, considering its depth. If the air in the flask is warmed, it presses harder against the water, and gets a little more room to expand in. But if the air in the flask is cooled, it presses more feebly, and is driven inwards. The air above the earth now forces the water a little farther into the tube.

Density.—When the air in a bottle is warmed, it tries to expand, and if there is an outlet, some of it will escape. Then of course there is less air in the bottle than at first, but the bottle is still filled with air. The weight of the air is less, but it fills the same space as before. We say that the air in the bottle is *less dense*—that is, a measured

quantity weighs less. This is a new and a hard word, but we must get used to it, and remember exactly what it means. Water is *denser* than air, because a pint of water weighs more than a pint of air. Mercury is *denser* than water, because a pint of mercury weighs more than a pint of water. Cold air is *denser* than warm air, because a pint of cold air weighs more than a pint of warm air. When air which is free to escape is warmed, it expands, and there is less of it in a measured space. It becomes *less dense* in consequence.

A thing which is denser than the liquid which surrounds it will generally sink to the bottom. If it is less dense it will generally swim on the top. Mercury sinks in water, because mercury is denser than water. Water sinks in air, because it is denser than air. If cold air and warm air are brought into the same room, the cold air will settle towards the floor, and the warm air towards the ceiling.

Fire-balloons are made on this principle. A sponge filled with alcohol is kept burning in the open mouth of the balloon. The flame heats the air in the balloon, which expands, and becomes less dense. The warm air inside the balloon is less dense than the outside air, and rises through it, carrying the balloon with it.

When part of the air in a room is warmed, it becomes less dense, and rises to the ceiling. It tries to escape, just as the air in the bottle did, and if the door is open it will escape at the *top* of the opening. Cold air will flow in at the *bottom* of the opening, to take the place of the air which has become warmed, and has risen to the ceiling. There will soon be a steady current or draught of air in the room, flowing inwards from the door, then passing upwards towards the ceiling, then outwards from the top of the

door. I can show you that such a current of air exists in this room.* I open the door a little way, and hold a lighted candle near the floor. The current of air blows the flame inwards—that is, towards the room. Now I hold the lighted candle near the top of the door. The current blows the flame outwards. If there is an open fireplace in the room there will be a current setting in towards the chimney, and this may make an important difference.

Capacity for Heat.†—I have here a cake of wax about four inches across and a quarter of an inch thick, which I place on the ring of a retort-stand. Here are also three bullets of the same size, one of iron, one of lead, and one of zinc. All three are suspended by threads from a wooden bar, and hang down into a vessel of water, which is kept boiling by a flame beneath. They have been there for several minutes, and are no doubt just as hot as the water in the vessel, and just as hot as each other. I will now lift the three balls out of the water at the same moment by means of the wooden bar, and lay them on the wax without touching one another. They melt the wax, and before long the iron bullet drops through. After some time the zinc bullet comes through. The leaden bullet does not come through at all, but turns cold first. You see that lead melts less wax than zinc, and zinc less than iron. Perhaps you will think that the bullets, though of the same size, were not of the same weight, and this is true. But the leaden bullet is the heaviest of the three, and yet it cooled first. If we had taken bullets of the same weight—

* Where there is a strong inward or outward draught, this experiment is liable to fail.

† Determine by previous trial the temperature at starting which will just enable the zinc bullet to pass through the cake of wax used for this experiment.

and this would have been the best way of making the experiment—the zinc bullet would have been the biggest, the iron bullet would have come next, and the leaden bullet would have been the smallest of the three. Lead is denser than iron, and iron is denser than zinc—that is, there is more of it in the same space. The iron bullet would still have come through first, the zinc bullet second, and the leaden bullet last, or not at all.

It is best in comparing the melting power of different metals to take equal *weights*, and not equal *sizes*.

What does our experiment prove? That equal quantities of iron, zinc, and lead, when raised to the same degree of heat, do not contain equal quantities of heat. We can melt more wax with one than with another. Some substances have a greater *Capacity for Heat* than others. It takes more heat to warm them up, and they give out more heat in cooling.

Water has a greater capacity for heat than any other common substance—ten times as great as an equal *weight* of iron, for instance, and more even than an equal *measure* of iron. There is no common substance which requires more heat to warm it, or which parts with more heat in being cooled, than water.

Conduction of Heat by Solids.—Here are two pieces of stout copper wire, of the same length, about six inches. One of the two has a long strip of paper tightly wound round one end. I will ask two of you to take each a wire, and hold the end in this flame. The end wound with paper is meant to be held in the hand. Which will hold the wire longest in the flame? You know beforehand, of course, but nevertheless we will see for ourselves. Yes, it is as we all expected. The bare wire has grown too hot to

be held any longer, but the wire which is wound with paper is not uncomfortably hot. Heat passes quickly along the wire, and reaches the fingers of the person who is holding it. Heat passes very slowly through paper, and if paper is placed between the wire and the fingers, it will stop most of the heat. Copper wire is a *good conductor* of heat, and paper is a *bad conductor*.

I have two spoons here, one of silver* and one of wood, and a pan of boiling water. I will ask one of you to stir the boiling water with the silver spoon, while another stirs it with the wooden spoon. We shall see who goes on longest. It will not be long before the silver spoon gets too hot to hold, but the wooden spoon will not feel hotter than it did at first. Silver is therefore a better conductor than wood. Metals are generally good conductors. Wood, stone, glass, and paper, are bad conductors.

Conduction of Heat by Liquids.—What sort of conductors are liquids, good or bad? We can soon find out. Here is a large glass bowl full of water. I will warm the water at the top by the smaller floating beaker, which I fill half full of nearly boiling water. Now we want to find out whether heat is conducted by the water to the bottom of the bowl. Let us use our air thermometer to see whether this is so or not. The air thermometer is very good for pointing out small differences of temperature.† We must load the ball of the air thermometer with shot, so that it will sink to the bottom of the bowl. Now we have everything ready, and I float the hot water beaker in the bowl. See whether the coloured fluid in the tube of the

* Pewter will not do instead of silver.

† *Temperature* means *degree of heat*. To know the temperature of a body

air thermometer moves at all. If the water at the bottom of the bowl is heated, the coloured fluid will rise in the

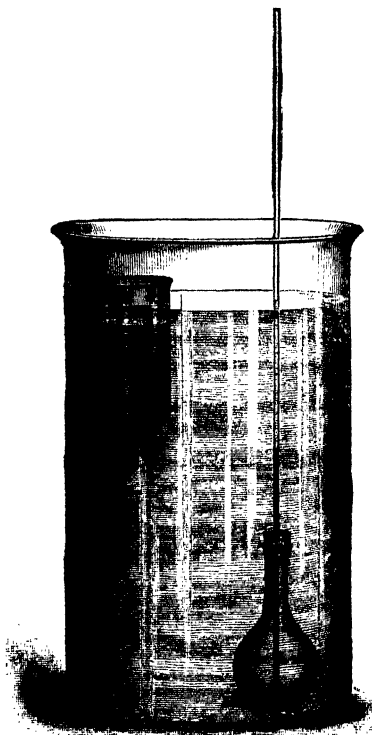


Fig. 114.—EXPERIMENT ON CONDUCTION OF HEAT BY WATER.
(The air thermometer shown here is described in the note on page 190.)

tube. But there is no change. In half an hour there will be no change worth speaking of. *Water is thus shown to be a very bad conductor of heat.* I can hold a test tube full of water in my hand, and warm the water at the top

over a flame until it boils, without feeling any change of temperature at the bottom, where my hand is.

Conduction of Heat by Gases.—Air and all gases are very bad conductors of heat, but I cannot think of any quite simple experiment to prove that they are so. This is because they move about so easily, especially when they are warmed on one side more than on the other. They *carry* the heat without *conducting* it.

Perhaps some of you know that in Russia and other very cold countries people use double windows, one inside the other, and find them a great comfort. Air is imprisoned between the inner and the outer window, and the heat of the rooms can hardly make its way through this air, so that most of it is kept inside. Our clothes are very bad conductors of heat. It would be very uncomfortable for us if they were not, for if we were clad in good conductors, we should lose our heat very fast. Our clothes are all the warmer for having much air imprisoned in their pores. We find very loose woollen wraps as warm as much heavier things. The air, if it can be kept still, is soon warmed by our bodies, and it conducts the heat away very slowly. I have said that air and other gases are very ready to *carry* heat, though they *conduct* it so badly. They carry it much in the same way that a lighted match carries heat to the gas. The air gets heated, and moves to another place, and carries the heat with it. We call this *Convection of Heat*. Both liquids and gases *carry* heat very easily in this way, because they flow so easily. Heat cannot travel through solids by convection.

Convection of Heat in Water.—Let us set up some convection-currents in water. We can do so very soon either by heating it from below or by cooling it from

above. I will try heating the water in this large beaker from below. A flame placed beneath the beaker will do all that we require. As the water at the bottom of the beaker gets warm, it becomes less dense, and rises to the top. More water takes its place, flowing in from the sides of the beaker. This is continually supplied from above, and so a circulation is set up. Upwards in the centre, outwards over the top, downwards along the sides, inwards along the bottom—that is the course of the current. If I put some wet bran in the water, you will see the currents for yourselves.*

Convection of Heat in Air.—Let us suppose that we have a room closed entirely, and with a lighted lamp in the middle of the floor. Convection currents of air will be set up, just like the currents of water in the beaker. There will be an ascending current over the lamp, outward currents along the ceiling, downward currents along the walls, and inward currents over the floor. These convection currents spread the warm air or the warm water over the whole space, and thus help to keep up an equal degree of heat all over.

Radiation of Heat.—I have told you of two ways in which Heat travels. These are Conduction and Convection. There is a third way, more interesting and more difficult to understand than either of the others. Conduction takes place with extreme slowness. Convection may be much more rapid, especially in air. But in the third way which I am going to tell you of, Heat travels with incredible speed, as fast as Light. It can travel from the sun to the earth in a very few minutes, and from any point on the

* If the bran is not thoroughly soaked it will float at the top. The best way is to boil it beforehand.

surface of the earth to any other in sight, faster than any timekeeper that you know of can measure. We call this third way *Radiation of Heat*.

Heat can be radiated through empty space, where there is not even air. It passes with the greatest ease from the sun to the earth, though there is, so far as we can tell, no substance whatever, solid, liquid, or gas, for almost the whole distance.

Heat is *radiated* equally on all sides from the hot body. It does not matter where you place your thermometer, above or below, it will be equally affected by the Heat radiated from the hot body, provided that the distance is the same, and that no substance comes between to stop the radiation.

Radiant Heat travels through space in straight lines, and with the speed of Light.

Radiant Heat can pass through some substances, such as perfectly dry air, without perceptibly warming them.

In these respects Radiation of Heat is very different from either Conduction or Convection, but it is just like Light. Indeed, it is not quite proper to speak of Radiant Heat as a different thing from Light. The more we know about them, the more clearly we see that they are only different forms of the same thing.

Warming by Radiation.—When we warm ourselves in front of a fire we receive the Heat by Radiation. You would be inclined to think that we get the Heat from the warm air, but the fire will warm you even when the air between you and it is cold. I have stood before a furnace when a frosty wind was blowing between it and my body, but the Heat of the furnace was easily felt. The sun warms us when the air is intensely cold. Hold a thermometer in

front of the fire and see how rapidly the mercury rises. But a sheet of paper held between the fire and the thermometer will soon send the mercury down. If the Heat were *conducted* or *conveyed* by the air, the paper would make little or no difference.

Radiant Heat is much pleasanter as a means of warming a room than the Heat conveyed by circulating air. We enjoy warmth and cool fresh air all the better when we get both together. When a room is heated by an open fire, the air may be quite cool, though the walls and the bodies of persons in the room are comfortably warmed.

The Heat which this gas flame gives off may travel in three different ways at the same time.

Part of it warms up the brass tube of the lamp, and is *conducted* away, very slowly, and for a very short distance.

Part of it warms the air above the flame, which rises and *conveys* away the Heat.

Part of it is *radiated* with the speed of Light to all parts of the universe not shut off by substances which stop Heat, and which are, as we say, *opaque* to Heat.

LESSON XVIII.

AIR AND BURNING IN AIR.

This Lesson will require about two hours. It will be found convenient to divide it into two parts, beginning the second part with a short recapitulation of what has already been gone over. The teacher should be possessed of at least such an elementary practical knowledge of Chemistry as would be acquired in a short course of Laboratory work.

Air felt but not seen.—We cannot see, taste, or smell pure air. How do we know that there is any such thing? Because we can *feel* it. If we wave our hands rapidly, we *feel* that they pass through something which resists, though very slightly. When air is in very rapid motion—for instance, when a gale of wind is blowing—we have good proof that this invisible substance is a real thing, which can raise waves and tear branches off trees.

Air can be poured.—I will now show you that air can be poured from one vessel into another, and that though you cannot see air, you can see that it is present in a vessel. I have here a trough for collecting gases under water, called a *Pneumatic trough*. I fill the trough nearly full of water; then I dip a wide-mouthed bottle in the trough, fill it with water, turn it upside down, and hold it in one hand, mouth under water, so that it remains full. Next I take a common bottle, filled with nothing but air, and plunge it mouth downwards into the trough. The air cannot escape, and is now imprisoned in the bottle. Then I bring it under the open mouth of the other bottle, and cautiously slope it upwards, so that bubbles escape one by one, and rise through the mouth into the bottle above. As

the air passes in, the water passes out, and now our wide-mouthed bottle is half full of air. We have poured the air from one bottle into another, and kept it from mixing with the air outside. You see that when we pour air into a vessel filled with water, we always have to pour *upwards*. Why? Because air is less dense than water, and rises through it.

The Pneumatic trough is very handy for collecting gases, and we shall make use of it in this very lesson.

What is air made of? That is a rather hard question, but still it is a question which can be answered, and I am going to try to help you to answer it to-day.

What is a Gas?—Air is an invisible *gas*. Why do we call it a gas? Because it will not lie still in any place where it is put, but spreads out and mixes with any other gases which are close at hand. If I put a marble into an empty cup, it will rest there and keep its spherical shape. That is how *solid* things behave. If I pour water into an empty cup, it will lie at the bottom, but it will immediately take the shape of the inside of the cup. That is how *liquids* behave. If I pour coal-gas, or any other gas, into an empty cup, it will not stay there a minute, but will escape and mix with the air around. That is how *gases* behave.

Some common Gases.—There are many different gases. Let us mention some. There is the coal-gas which we burn for lighting rooms and streets. There is the strong-smelling gas which comes from a bottle of smelling-salts. There is another quite different gas, which bubbles up when a bottle of soda-water or lemonade is opened. Air is a gas, too, but it is not exactly like any of the rest.

Some Gases cannot be breathed.—What is the

difference between air and coal-gas, or smelling-salts gas, or soda-water gas? There is one difference of great practical importance. You can breathe air; but if you were to go into a room filled with coal-gas, you would turn dizzy and fall on the floor, and in a very short time you would die by poisoning. Smelling-salts gas would cause you great pain and choking, and even death, if you breathed much of it. Soda-water gas would stupefy you, and if you were to go by yourself into a place that was filled with it, you would never come out alive. But pure air does not choke or stupefy us; it is wholesome and necessary to life.

Air necessary to burning.—Many things will *burn* in air. A candle burns bright as long as it has a good supply of fresh air, but goes out if the supply of air is stopped. We will put a short piece of candle in a saucer, light it, and then cover it with a wide-mouthed bottle turned upside down. Before long the flame gets smaller, and in a minute or two it goes out altogether. Coal will not burn without air. Even coal-gas, which takes fire so easily, must have a good supply of air, or it will not burn at all.

The burning of Lead.—Have you ever watched a plumber melting Lead in an iron ladle over the fire? I daresay you have noticed that a scum soon appears on the surface of the bright Lead, and that if the scum is cleared off, it begins to form again directly. You might go on skimming the Lead time after time till all the Lead was used up, and turned into a heap of dirty powder. This is the result of heating Lead very hot in air. We might call it *burning* the Lead, though no flame is produced.

The burning of Copper.—Other metals may be burnt in the same way. We will next take some bright Copper

turnings,* and put them into the middle of a piece of hard glass tube about six inches long and half an inch wide, open at both ends. Then we will clamp the tube in a gently sloping position to an upright stand, and put a flame under the middle, where the heap of Copper lies. Before long the bright Copper turns black on the surface. If we were to heat it for two or three hours, all the Copper

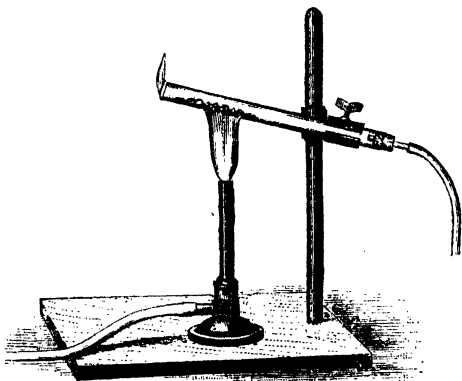


Fig. 115.—COPPER HEATED IN COAL-GAS.

would be changed into black scale. But we need not wait for that. It is enough for you to see that if Copper is strongly heated in air, it *burns* like lead, and changes to a powder or scale.

Copper heated in Coal-gas.—Would Copper burn in the same way in any other gas? Let us try whether it will burn to black scale in coal-gas. We will take the tube just as it is, with the blackened Copper inside, add a little bright Copper, and by means of a cork and a narrower

* The turnings may perhaps be greasy. Wash them well with caustic soda, and afterwards with water, then allow them to dry.

tube passing through the cork, connect it with an india-rubber gas-pipe. I will pass a gentle stream of coal-gas through the tube, and to prevent accidents we will light the gas at the open end of the tube. Now I put a flame under the Copper as before. Let us watch it, and see whether the bright Copper blackens. Not at all! The bright Copper remains bright, and in a few minutes the blackened Copper returns to its original red colour.

This experiment shows us that strong heating in coal-gas does not blacken Copper, but restores it when blackened. The blackening of the Copper is not brought about by mere heating, but by heating in *air*, and perhaps in some other gases also which we have not tried.

The experiment tells us something else. It tells us that the Copper did not go away altogether when heated in air; it did not pass off as vapour, but remained in the tube, and now we have brought it back to something like its original appearance.

The burning of Quicksilver.—Other metals besides Lead and Copper burn in air, and form substances which differ from the pure metal, though they contain it. The curious liquid metal, called Mercury or Quicksilver, burns to the beautiful red powder* which I have here. If this powder is heated in coal-gas, it turns to bright, liquid Quicksilver, just as the black Copper scale turned to red, metallic Copper.

The Metals not destroyed by burning.—The red powder of Mercury can be made to give back the liquid metal by mere heating, even in air, though the Copper scale will not give back metallic Copper by heating in air. The metal is really there in both cases. The red powder

* Mercuric Oxide.

contains Quicksilver; the black scale contains Copper. But they are united to something which they have got from the air, and the Copper is more firmly united than the Quicksilver. Mere heat will set the Quicksilver free, but if you want to set the Copper free, you must heat the Copper scale in a gas which contains none of the scale-forming substance. We used coal-gas, and that was found to answer.

Recovery of the Quicksilver.—Let us put a few grains of the red powder into a narrow glass tube closed at one end.* You will see directly that a short or wide tube would not do. Heat the powder in the tube over a Bunsen burner. Before long it darkens, and then wastes away. Now look at the upper part of the tube. It is lined with a grey film. Take a little roll of paper which will just fill the tube; pass it into the end of the tube, and turn it round once or twice. The paper wipes up the Quicksilver, and gathers it together into drops. We have got back the true liquid metal by heating the red powder, which was obtained in the first place by burning Quicksilver in air. How has this come about? The heat of the flame separated the Quicksilver from the red powder, turned it into a gas or vapour of Quicksilver, and this passed up the tube. When it came to the cold part of the tube, it turned to liquid Quicksilver again, just as steam turns to water when it is cooled. If we had not used a long narrow tube, the vapour would have escaped before it became cooled.

Have you ever seen steam turned into water? It is very easy to show you this every-day occurrence. I have a kettle boiling briskly, and I hold a cold plate in the steam

* The tube should be about four inches long and about a quarter of an inch wide. Such a tube may be made by sealing up one end of a bit of glass tubing.

which comes out of the spout. In a moment the plate is covered with drops of water. Water, you see, can be a gas at one time and a liquid at another. Is it ever solid? Yes: Ice is solid Water.

The Red Powder consists of Quicksilver and something else.—The red powder of Quicksilver, when heated, gives off a gas which runs to drops of Quicksilver as soon as it is cooled again. Does it give off anything else? I think I can show you that it does, that it gives off a second gas, which is not Quicksilver-gas, and is not common air. This will require a little preparation. How can we collect the gas, and examine it? We must be careful not to let it mix with the air around, for we should never be able to separate it again. You remember the Pneumatic trough, which we used to pour air from one vessel into another? That will do.

The Gas collected.—Now I will put some more red powder of Quicksilver into a test-tube fitted with a cork, through which a bent tube passes. I will dip the end of the bent tube into the water, and have ready a second test-tube filled with water, and held mouth downwards on the beehive shelf inside the trough. That is meant to receive the gas. Next I will heat the red powder as before. Bubbles are immediately given off, but these are nothing but air expanded by heat. (See Lesson XVII.) After a minute or so bubbles begin to come off more freely, and now we will collect these in the inverted test-tube. When the bubbles begin to slacken I remove the hot tube, and lay it aside.

Properties of the Gas Oxygen.—The gas which we have collected has no colour. Is it common air? Let us see whether a light will burn in it? I place my thumb

over the mouth of the tube, and remove it from the water. Then I put a glowing match (not flaming but just blown out) into the tube. See how it bursts into flame! Things which burn gently in air burn brilliantly in this gas. This cannot be common air! But it is contained in common air. It is called *Oxygen Gas*. The Quicksilver got this Oxygen from the air, and united with it to form a red

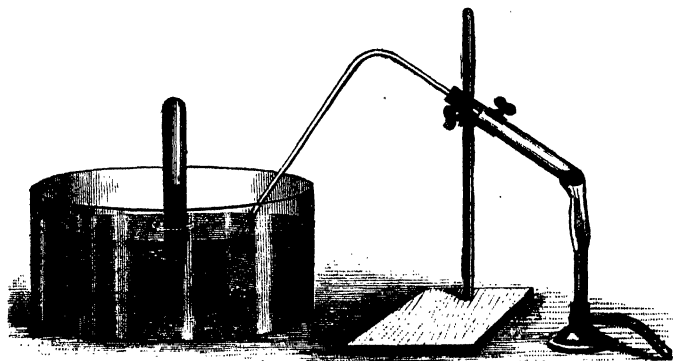


Fig. 116.—GAS OBTAINED BY HEATING RED POWDER OF QUICKSILVER.

powder. The Copper got Oxygen from the air, and united with it to form black scale. The Lead got Oxygen from the air, and united with it to form a yellow scum.

The Oxygen is the part of the air which helps things to burn. If air consisted of nothing but Oxygen, fires and flames of all kinds would burn ten times as fiercely as they do. The Oxygen of the air is evidently mixed with some other gas which checks burning, and makes it go on at a moderate rate. Can we get some of this other gas? If we could remove all the Oxygen from common air, perhaps we might leave the other gas behind, and collect it, and

examine its properties. But how can we remove all the Oxygen from common air? Lead, Copper, or Quicksilver would do it for us, if strongly heated, but there is an easier way still. We will take a substance which burns very easily, and burns out very completely so long as there is any Oxygen left. This substance is Phosphorus. I



Fig. 117.—PHOSPHORUS BURNT IN AIR.

must warn you that Phosphorus is a dangerous substance to handle, just because it takes fire so easily. It must be kept under water, and cut under water, and never touched with the fingers.

The burning of Phosphorus.—We will first place a small bit of Phosphorus, about half as big as a coffee bean, in a small cup or crucible, standing on a common plate. I will light the Phosphorus with a warm wire, and then cover it up with a large, dry, wide-mouthed bottle. The Phosphorus burns very readily, and as it burns thick white

fumes are given off. They will slowly settle down, and form a sort of white snow within the jar. This white snow answers to the yellowish powder formed when Lead burns, to the black scale formed when Copper burns, and to the red powder formed when Quicksilver burns. Try the effect of water upon it. It dissolves in water like sugar.

What is left when all the Oxygen is removed from Air.—Now we will burn out all the Oxygen from the air imprisoned in a bottle, and see what is left behind. I take a jar open both at top and bottom. The lower end must be placed in water on the shelf of the Pneumatic trough. The upper opening forms a neck, which can be quickly and perfectly closed by a glass stopper. We will smear the stopper with tallow, to prevent any of the air or gases from escaping. Now I float a little cup containing a small bit of Phosphorus on the top of the water inside the jar, and lower a hot wire from above. In performing this experiment, do not forget that the air will be expanded by the heat of burning, and will escape from the jar unless precautions are taken. Lower the jar into water with the stopper out, so that the water stands at the same level inside and out, and take care that the water is deep enough to give a margin for expansion. As soon as the Phosphorus takes fire, I withdraw the wire, and press down the stopper, so as to seal up the jar instantly. The Phosphorus blazes up, then slackens, and finally dies out. The jar is filled with white fumes.

Do you notice that while the Phosphorus was burning, the water rose in the jar, and now fills about a fifth part of the space which the air occupied? About a fifth part of the air has been removed by the burning Phosphorus, and that is the Oxygen which it contained. What is left? A

colourless gas. We may suspect that this gas will not burn, or help Phosphorus to burn. If it could have done either, it would have disappeared with the Oxygen. But we will lower a lighted candle into it, first arranging that the level of water is the same inside and outside.* I remove the stopper for a moment, and lower a candle end by means of a wire into the jar. The flame goes out instantly as if it had been plunged into water. The new gas will not support a flame. We call it Nitrogen.

Air composed of Oxygen and Nitrogen.—Air is made up of about one measure of Oxygen to four measures of Nitrogen. It is the Oxygen which enables fires and candles to burn, which forms a scum, or rust, or scale, or powder, upon bright metals. It is the Oxygen which is useful to us for breathing. The Nitrogen has no strongly marked properties. It will not burn; it will not support flame; it does not readily unite with metals. It serves to dilute the Oxygen and weaken its effects. If your tea is too strong, you add water to dilute it, and make it milder. Nitrogen dilutes the Oxygen of the air, as water dilutes strong tea.

Oxides.—Various metals, as we have seen, unite with the Oxygen of the air, and form compounds which are called Oxides. What is the Oxide of Lead? Of Copper? Of Quicksilver?

Where did these metals get their Oxygen to form Oxides? From the air. How can the Oxygen be separated from the metals again? Sometimes, but not always, by heat.

When anything burns in air, it unites with the Oxygen

* Bring the water to the same level inside and outside the jar before taking out the stopper. Otherwise, air will rush in and mix with the gas inside.

of the air, and all such burning lessens the quantity of Oxygen. If there is only a little air shut up in a small space the Oxygen will soon be used up by burning. Hardly anything will be left but Nitrogen, and the flame will go out.

Fumes of Phosphorus dissolve in Water.—One thing still remains to be done. By this time the white fumes have disappeared. There is no snow lying on the water, as there was on the plate in the previous experiment. It has dissolved in the water, but I can show you that it is still there.

The Fumes make the Water Acid.—Here are three glass beakers, two of which contain pure water; the third is empty. I pour into this last some of the water over which the Phosphorus was burnt. Into the second beaker I pour a few drops of vinegar. The first beaker I leave just as it is, filled with pure water.

Here is a bottle full of dark blue fluid. It is a solution of *Litmus*, obtained from a certain kind of plant. I pour a few drops of the litmus into the first beaker, which is full of pure water, and stir it up with a clean glass rod. The water is tinged with a pale blue colour. Then I pour two or three drops into the second beaker, which contains a little vinegar, and stir as before. The blue colour changes to red. All common acids produce the same effect, so that we call this a *test for acids*. If you want to know whether a fluid is acid or not, put a little into a solution of litmus, or pour the litmus into the fluid. If the litmus turns red, the fluid is acid. Now we will try the third beaker, which holds some of the water over which the Phosphorus was burnt. I add some litmus to it, and stir gently. The blue changes to red. This is proof that when Phosphorus unites

with Oxygen in burning it produces an acid substance. You remember that this substance at first makes white fumes, and in a dry jar the fumes settle down like snow. They easily dissolve in water, and make the water acid.

Summary.—What have we learnt about Air and burning in Air? The chief points are these:—

1. Many things burn in Air. When they do so, they unite with the Oxygen of the Air, and form Oxides.

2. The original substance can sometimes be recovered by heating the Oxide in a gas which contains no Oxygen. How can you recover Copper from the Oxide of Copper?

3. Oxygen is a gas contained in common Air, of which it forms about a fifth part by measure. The rest of the Air consists almost entirely of Nitrogen.

4. It is the Oxygen which helps things to burn. The Nitrogen weakens the effect of the Oxygen.

LESSON XIX.

CARBON AND CARBON DIOXIDE.

WANTED:—*A few of the commonest appliances of a school laboratory.*

This Lesson will require about two hours. It will be found convenient to divide it into two parts, beginning the second part with a short recapitulation of what has already been gone over.

Wood turned to Charcoal.—I have here a small iron pot—the outer part of a glue-pot, as it happens. I fill it with sand, and plunge a bit of stick (a short piece of a pen-holder) into the sand until it is quite buried.

I mean to change the stick of wood into a stick of Charcoal by heating it. What is the sand for? My next experiment will answer that question. Now all is ready. I put the pot, with the sand and stick inside, over a Bunsen burner, which is a hot and smokeless gas-flame. Now the pot has become hot—so hot that I cannot touch it with my fingers. The sand begins to smoke, and there is a smell of burning wood. After a while the smoke ceases to come off. That is a sign that our experiment is ended. I empty the iron pot over a sheet of iron plate, and now we see a black stick in the midst of the sand. That is a stick of Charcoal or *Carbon*. Why need we have a second name? Would not *Charcoal* be enough? Because all Carbon does not look like this, and all Carbon is not made in the same way. A piece of cinder is nearly pure Carbon, but it is not Charcoal. Soot is nearly pure Carbon, but it is not Charcoal. It has been proved that Charcoal, and Cinder, and Soot consist almost entirely of one kind of stuff, which is named Carbon. Black Lead and Diamonds are also made of pure Carbon.

The Effect of heating Charcoal in Air.—I break the little stick of Charcoal into two, and put half of it in this iron spoon. Then I hold the bowl of the spoon over the Bunsen burner. I have fastened a stick to the handle of the spoon with a piece of wire, to prevent the hot iron from burning my fingers. The spoon soon gets hot and the Charcoal begins to glow. Now it is getting smaller. It wastes away, and leaves nothing behind but a little white ash. What has become of the Charcoal? The next experiment will show us. Now you will see, I think, why we put sand into our iron pot. When the Charcoal was surrounded by sand, it did not waste, though it was made very hot. When the sand is taken away, the Charcoal

wastes as soon as it becomes very hot. I heaped sand round the stick in the first experiment because I wanted to save the Charcoal by keeping the air from it.

The Gas formed by heating Charcoal in Air.—What happens when the Charcoal wastes? A gas is formed which possesses some peculiar properties. Let us put a bit of Charcoal into a glass tube, and heat it till it begins to glow. It soon wastes, and nothing remains but an almost invisible white ash. Now I light a match, and pass the lighted end into the same tube. It goes out at once, almost as suddenly as if it had been plunged into water. I light another match, and pass it in the same way into a second tube, which has had no Charcoal heated in it. The match remains alight for a short time. Thus we learn that when Charcoal wastes, a gas is formed which extinguishes flame. Common air, as we see, does not extinguish flame.

Charcoal-gas (Carbon Dioxide) turns Lime-water milky.—Charcoal-gas has another property which distinguishes it from common air. I take a glass test-tube, and connect it with a bent glass tube by means of a cork through which a hole has been drilled. The cork fits tightly both to the tube outside and to the tube inside. No gas or air can leave the test-tube except through the bent glass tube. Now I heat the test-tube over the flame, and at the same time plunge the end of the bent tube beneath the surface of the water in this glass beaker. The water is not exactly common water; it has some Lime dissolved in it, and is called *Lime-water*. The air bubbles up through the Lime-water, but causes no visible change in it. Thus we find that common air driven out from a tube by heat, and made to bubble up through Lime-water, does not

alter the appearance of the Lime-water. Now let us try our Charcoal-gas. I fit up the experiment as before, except that I first fill the test-tube with Charcoal-gas. You know how this is done. We must put a bit of Charcoal in the tube, and heat it till it glows. The gas is now seen to bubble through the Lime-water, and as it does so the clear Lime-water turns milky. Charcoal-gas therefore turns Lime-water milky, and it may be recognised by this property.

An easier way of making Charcoal-gas (Carbon Dioxide).—Charcoal-gas (which chemists are accustomed to call *Carbon Dioxide*) may be extracted from Chalk, and this is an easier way than by heating Charcoal in a test-tube. I take another test-tube, and put a little Chalk in the bottom of it. Then I pour a little acid * mixed with water upon the Chalk. A crowd of very small bubbles of gas appears on the Chalk. The gas rises through the fluid, and fills the tube. I put a lighted match into the tube, and it goes out. I fit a cork and bent tube to the same test-tube, and plunge the end of the bent tube into Lime-water. It is not necessary this time to heat the test-tube, for the gas bubbles up at once through the Lime-water, and turns it milky. Charcoal-gas, or Carbon Dioxide, is therefore produced by pouring hydrochloric acid upon Chalk. We have not proved whether the Carbon Dioxide comes from the Chalk or from the hydrochloric acid, but the point can be settled by taking a little trouble.

Carbon Dioxide obtained by heating Chalk.—I put some Chalk into this small iron bottle† which has a metal

* Hydrochloric acid is suitable.

† A piece of glass combustion-tubing fitted with a bent glass tube will do, if a suitable iron bottle is not at hand. Do not forget to remove the tube from the water before the bottle or tube begins to cool. There will be an explosion if water is allowed to run up the tube.

pipe attached. Then I clamp it to a stand, and play upon it with the flame of a large Fletcher blow-pipe. When the iron bottle is white hot, I lift the beaker of Lime-water to the nozzle of the metal pipe, and let the gas bubble through the Lime-water. It turns the Lime-water milky. I let some of the gas stream into a test-tube, and find that it extinguishes a lighted match. We see then that the Chalk contains Carbon Dioxide. All the Carbon Dioxide we got by pouring acid upon Chalk came from the Chalk.

Carbon Dioxide in Water is Acid.—I will next show you the result of making some Carbon Dioxide bubble up through litmus-water. We will extract the Carbon Dioxide from Chalk by acid, as in the last experiment but one. When the gas bubbles up through the blue litmus solution, the blue colour changes to red, and you recollect that this is a proof that the solution of Carbon Dioxide in water is *acid*. This is why Carbon Dioxide is often called *Carbonic Acid*, or *Carbonic Acid Gas*.

Blowing through Lime-water turns it milky.—Our next experiment is a very simple one. I take a beaker full of Lime-water, and blow through a glass tube into the beaker, making the air from my lungs bubble up through the Lime-water. The Lime-water at once begins to turn milky. What does this show? That there is plenty of Carbon Dioxide in my breath.

Lime-water exposed to the Air turns milky.—I take another beaker of Lime-water, and leave it on the table. We shall find to-morrow that there is a thin film on the top of the Lime-water. After a few days the Lime-water will be quite milky. What does this show? That there is a very little Carbon Dioxide in common air.

Now let us ask another question. Why does Lime-water turn milky when Carbon Dioxide is mixed with it? To answer this question, we must try to find out what change has taken place in the Lime-water, and what is the substance which has formed in it and made it milky. What is Lime-water made of? You say, Lime and water—Lime dissolved in water. That is quite right. What is milky Lime-water made of? We must evaporate or dry up the water, and see what is left. This is a tedious business, and we cannot stop to see it done. When all the water is got rid of by gentle warming, a white powder will remain in the vessel. This powder is not Lime, but Chalk. How can we be certain that it is Chalk, and not Lime? Both are white powders, very much alike at first sight. Yes, but Chalk, as we have seen, *effervesces*, or bubbles up, when acid is poured upon it. Lime does no such thing. If you pour acid upon the sediment of milky Lime-water, it will effervesce and give off plenty of Carbon Dioxide.

Lime-water turns milky when Carbon Dioxide passes into it, because the Lime and the Carbon Dioxide combine to form Chalk, and the Chalk is almost incapable of dissolving in water. We should require a great deal of water to dissolve a single tea-spoonful of Chalk. The white Chalk becomes visible, and turns the water milky, simply because it is *insoluble* in water.

Now I will put you through a few questions to see that you understand what has been said. What is Chalk? It is a compound of Lime and Carbon Dioxide. How do we know that? Because when we heat Chalk very much, Carbon Dioxide is driven off, and Lime is left behind. If this Lime is dissolved in water, it makes Lime-water, and this turns milky again and forms Chalk, as soon as Carbon Dioxide

is added to it. Then Lime and Carbon Dioxide together make Chalk. Take away the Carbon Dioxide from Chalk, and you get Lime. Make Lime unite with Carbon Dioxide, and we get—what? Chalk, of course. Can you tell me a second way of separating Carbon Dioxide from Chalk? I have just reminded you that heating the Chalk is one way—what is the other? Yes, I see that you know. Pouring acid on the Chalk is the other way.

Carbon Dioxide consists of Carbon and something else. What else? Something which is contained in common air, for Carbon Dioxide can always be got by burning Carbon in air. Now air consists of Oxygen and Nitrogen. Which of these two gases unites with the Carbon to form Carbon Dioxide? It is not likely to be the Nitrogen, for that is very slow to unite with Carbon, if it does so at all. We have seen that Carbon and even Phosphorus will not burn in Nitrogen. (See Lesson XVIII.) But Carbon burns in Oxygen with great ease. I will show you the difference.

Carbon heated in Nitrogen will not burn.—Here is a jar which I have filled beforehand with Nitrogen. I will bring some Carbon into the tube, and heat it there. We can do this by lighting a splinter of wood and passing it alight into the tube. It goes out immediately, and there is no sign of combination or union between the Carbon and the Nitrogen. In fact, they cannot be made to unite—at least, by any means which we can make use of here.

Carbon heated in Oxygen burns brilliantly.—Now we will try the effect of heating Carbon in Oxygen. Here is a second jar, which I have filled beforehand with Oxygen. I light the splinter of wood once more, blow out the flame, and pass the glowing end into the jar. It

bursts afresh into flame, and burns with a brilliant light. As soon as the Charcoal ceases to glōw, I remove the splinter, and close the jar with a stopper.

You will now have no doubt that when Carbon burns in air, it unites with the Oxygen of the air, and not with the Nitrogen. But we will prove the point more completely still.

Carbon burnt in Oxygen forms Carbon Dioxide.—When Carbon burns in air, Carbon Dioxide is produced. If we burn Carbon in Oxygen, shall we form Carbon Dioxide? If we do, we shall know that burning in air is simply burning in dilute Oxygen. I take the jar in which we have just burnt the piece of Charcoal, and pour Lime-water into it. The Lime-water turns milky when shaken up. This shows us that burning in air is really burning in dilute Oxygen. The substance formed is the same in both cases—that is, Carbon Dioxide. The burning of Carbon in air or Oxygen means the union of Carbon with Oxygen to form Carbon Dioxide.

The Carbon in Carbon Dioxide made visible.—Can we get back the Carbon which is contained in Carbon Dioxide, so as to see it? Yes, we can. To do this, we must put into Carbon Dioxide some substance which unites with Oxygen more eagerly than Carbon does. Perhaps we may find a substance which will take all the Oxygen to itself, and leave the Carbon behind.

This bright silvery metal, Magnesium, shows a great readiness to unite with Oxygen. I heat the end of this bit of Magnesium ribbon, and it burns with a brilliant light, leaving behind a white powder, which is an Oxide of Magnesium—that is, a compound of Magnesium and Oxygen. If we can persuade Magnesium to burn in

Carbon Dioxide, we may possibly remove the Oxygen from the gas, and leave the Carbon behind.

I have here a glass jar, filled beforehand with Carbon Dioxide. I light a bit of Magnesium ribbon, place it in the jar, and close it up at once. The Magnesium goes on burning. Now it is burnt out. What is left behind? A grey powder, which floats in the air, and slowly settles to the bottom. We will wait till the jar is quite clear. Now look into the jar. There is a quantity of white powder lying at the bottom. That is the Magnesia or Oxide of Magnesium. On the top of the Magnesia is a thin film of a black sooty substance. That is the solid Carbon recovered from the Carbon Dioxide. The Magnesium has taken away the Oxygen, and left the Carbon behind. Why does the Carbon lie on the top of the Magnesia? Because it is less dense, and settles down more slowly after all, or nearly all, the Magnesia has come to rest at the bottom of the jar. I will next remove all the sediment from the jar, and place it in a saucer containing some dilute Hydrochloric Acid. The Magnesia dissolves at once, and leaves all the particles of Carbon floating in the saucer.

Summary.—Let us now turn back for a moment, and see what our experiments have taught us. We have learnt:—

1. That a stick of wood contains a good deal of Carbon.
2. That Charcoal wastes when strongly heated in air, and forms a gas, known as Carbon Dioxide, which puts out a flame, and reddens Litmus-water, and turns Lime-water milky.
3. That Carbon Dioxide may also be prepared by pouring acid upon Chalk, or by heating the Chalk very much.

4. That there is much Carbon Dioxide in our breath, and a very little in common air.

5. That Lime and Carbon Dioxide united together make Chalk.

6. That Carbon Dioxide consists of Carbon combined with Oxygen.

LESSON XX.

THE COMPOSITION OF WATER.

This Lesson will require about two hours. It will be found convenient to divide it into two parts, beginning the second part with a recapitulation of what has already been gone over.

Is Water an Element or a Compound?—Water was for a long time thought to be an Element—what the old philosophers called a Simple. It was supposed to be made of one kind of stuff only, and people believed that by no contrivance could it be broken up into anything else. They had seen Water freeze, and afterwards run back to Water again; they had seen Water turned to steam, and afterwards condensed into Water again; and it seemed to them that Water was Water, and could never be split up into simpler substances. I will now show you one way of proving that Water is really a compound, made of other and simpler substances.

Sodium burnt.—Here is a piece of a rather uncommon metal, called Sodium. You may see that it is a metal from its appearance when freshly cut. It is easily cut with a knife, because it is soft: softer than lead. Notice that it

only remains bright for a moment or two.* Take a piece of Sodium about the size of a coffee-bean, and heat it strongly in an iron spoon. When it gets hot enough, you will notice that it burns with a beautiful yellow light. It does not all disappear, but there is left a whitish substance. You will remember that Lead and Copper can be burnt too, but Sodium burns more easily than either of these. When the spoon has cooled, dip it into a basin of water. The white substance dissolves in the water. Then add a few drops of red litmus solution.† This is a vegetable colour reddened by acid. You see that it is turned blue by the liquid in the basin.

Sodium floats on Water, and soon disappears in it.—Now fill another basin with water, and drop upon the surface of the water a smaller piece of Sodium than that taken in the last experiment. You see that the metal is so light as to float on water; it fizzes and moves about, and is evidently being acted upon by the water. After a time it has entirely disappeared. What has become of it? Add a few drops of red litmus solution to the basin, and you see the same effect as before. The Sodium or the burnt Sodium is evidently dissolved in the water.

A Flame produced by Sodium and Water.—Let us now try the experiment in a slightly different way. Take a basin of water, and place on the surface a piece of blotting-paper. It will float, and soon get soaked through with water. Now drop a piece of Sodium on the

* In all experiments with Sodium great care must be taken to keep the bottle clearly labelled, and within reach of the teacher only. Quite small pieces, scraped clean, should be used. It is also particularly important that when it is placed in water the pupils should not stand too near, as there is a tendency for the molten caustic soda produced to fly.

† Made by adding the smallest possible quantity of acid to a solution of litmus.

blotting-paper. The Sodium fizzes as before, but the blotting-paper prevents it from moving about. You see the result. A flame is produced, like the yellow flame which the Sodium gave when it was heated in air. But it is not the metal that is burning this time; it is something that is escaping from the water. To show this we must try the experiment in still another way.

Why does the Sodium produce a flame when floated on blotting-paper, and not when it floats on water? The water acts upon the Sodium, and heat is produced. If the Sodium is kept still, the heat increases till a flame appears; but if the Sodium darts to and fro, it always meets fresh quantities of cold water, and never gets hot enough to make a flame.

A Gas produced by the action of Sodium upon Water.—Fill a large test-tube (a “boiling-tube”), or a wide-mouthed bottle, with water, and invert it in a basin of water, as if you were about to collect a gas. Then take a small piece of Sodium, and, holding it between the finger and thumb, bring it quickly under water, and let it slip up inside the inverted tube or bottle.* You see now what the fizzing meant. The tube is fast filling with a gas, and this gas is produced by the action of the Sodium on the water. It increases in quantity so long as any Sodium remains. Let us now see what this gas is. You do not know many gases yet, but you know Air, Oxygen, Nitrogen, Carbon Dioxide, and Coal-gas. We can easily tell if it is one of these by applying a flame. Think for a minute what will happen to a flame if put into each of these gases one by one.

* The experiment may be easily and safely made, but no time must be lost, as the Sodium soon heats when placed in water,

The Gas burns when lighted. It is Hydrogen.—Let us apply the flame, and thrust it well into the bottle. You see that it does not merely go out, as it would in Carbon Dioxide or Nitrogen, but though the flame itself goes out, the gas catches fire and burns. And yet it does not burn like Coal-gas. The flame is yellowish, like the flame we got from the Sodium on the blotting-paper; but it is paler than a Coal-gas flame, and the gas does not smell of Coal-gas. This is another gas, different from all those named above; it is called Hydrogen. Hydrogen, then, is a colourless gas, obtained from water, and it possesses the power of burning in air. What is formed when Hydrogen burns in air?

Another way of preparing Hydrogen.—In order to find out what is formed when Hydrogen burns, and in order to have enough gas for further experiments, we must have a handier way of preparing it. We can prepare Hydrogen by pouring Sulphuric Acid diluted with water upon zinc in a bottle. An apparatus like that in the figure will

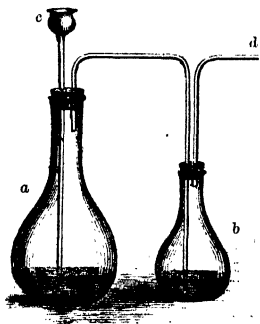


Fig. 118.—PREPARATION OF HYDROGEN.

do very well. The flask *a* contains Zinc clippings and water. The smaller flask *b* is half filled with strong Sulphuric Acid, which has the power of absorbing water eagerly. In order to produce the Hydrogen, some Sulphuric Acid is poured down the funnel *c* from time to time. The gas is soon given off abundantly, and passes through the Sulphuric Acid in *b*, which removes any moisture it may

contain. The gas issues dry at *d*. The gas must on no account be lighted at *d* until all the air has been driven off by the Hydrogen.*

Hydrogen burns in Air and forms Water.—When this has been done, light the gas at *d*, and bring over it a large bell-jar. The flame of the dry Hydrogen is here paler than that of the Hydrogen prepared by Sodium. In fact, the yellowness then seen was partly due to Sodium burning along with the Hydrogen. We have seen that Sodium burns in air with a yellow flame. Notice now that the outside of the bell-jar becomes dim. Draw your finger along it. You see that it is really moist. Where does this moisture come from? Not from the Hydrogen only, because you have dried the gas by means of Sulphuric Acid. Not from the Air only, because warming the air would make it take up more water rather than throw it down. And surely it does not come from the glass, which was clear and dry to begin with. The Water has been produced by burning the Hydrogen. It seems that Hydrogen is one of the things of which Water is made up. For Hydrogen can be got from Water by means of Sodium, and now we find that when Hydrogen burns in air, Water is formed. What else does Water contain? What does the Sodium take from the Water when Hydrogen is set free? and what does the Hydrogen unite with when it burns and forms

* This precaution cannot be too rigorously enforced. In order to be sure that it is safe to light the gas, a small test-tube must be held almost vertically, mouth downwards, so that the end of *d* just passes into it. After holding in that position for two or three minutes, the thumb must be slipped over the mouth of the test-tube which is brought *mouth downwards* to a flame. If on removing the thumb the gas burns quietly, it is safe to apply a light at *d*. But if the gas "pops," with a small explosion, it shows that the air is not expelled, and that it is unsafe to apply a match to *d*. The gas must be tested in this way on all occasions.

Water? Since the Hydrogen burns in air, and, as you may easily prove, does not burn unless air is continually supplied, we conclude that it unites with something which is contained in air as well as in water. You will easily be able to tell me what that is. What does Air chiefly consist of? Oxygen and Nitrogen. Which of these have we found to

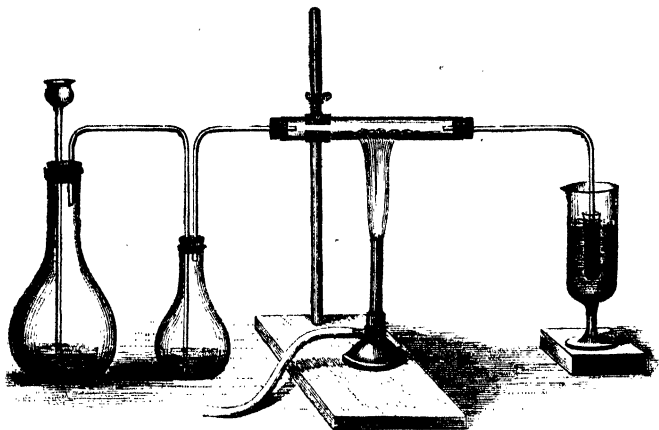


Fig. 119.—WATER OBTAINED BY HEATING COPPER SCALE IN HYDROGEN.

be helpful in burning operations? Oxygen. Then it is probably Oxygen with which Hydrogen unites to form water, when it burns in air. We will prove this by an experiment.

Hydrogen and Oxygen made to combine.—Take the tube used in the Lesson on Air and burning in Air to hold the Copper turnings, and fill it nearly full of black Copper scale (which can be bought under the name of Copper Oxide). Connect one end by means of a piece of india-rubber tube with the Hydrogen apparatus used in the last

experiment. To the other end of the tube containing the Copper scale, fit a bit of bent glass tube by means of a cork, and let this tube dip into a narrow test-tube, which is kept cool by a vessel of water. We are now going to pass Hydrogen over Copper scale. We know that Copper scale is composed of Copper and Oxygen, and we are going to see if the Hydrogen will rob the Copper scale of its Oxygen, and form water with it. Now set the Hydrogen apparatus going by adding some Sulphuric Acid. When all the air has been removed, begin to warm the Copper scale by heating the tube with a Bunsen burner. Soon you will see a change. The blackness of the scale gives place to the red colour of Copper, and this happens whenever the tube is heated. When you have carried on the experiment for some time, look at the test-tube, into which the outlet-tube dips. Is there anything in it? Yes, certainly, there are some drops of water. How have they come there? They have been formed partly from the Hydrogen and partly from the Copper scale. From what part of the Copper scale? From the Oxygen, of course. Here then we have a very good proof that water is made of the two gases, Hydrogen and Oxygen. We can now understand how Sodium acts on water. It unites with the Oxygen, and so the Hydrogen is set free. What does the Sodium form with the Oxygen? Sodium Oxide. You cannot see the Sodium Oxide, because it dissolves in the water, but you know that it is there by the litmus test. It was solid Sodium Oxide which you got when you burnt the metal in air. You saw then how easily it dissolves in water, giving a liquid which turns red litmus blue again.

Some kinds of Water are Soft, others Hard.—You have learnt that water is composed of Hydrogen and

Oxygen, but I must now tell you that this is only true of *pure* water. You know that salt water contains something else, and I daresay you have heard of "soft" water and "hard" water. Perhaps you have noticed the difference yourselves, for they differ a little in taste, and differ very much when you try to wash with them. It is not easy to get a lather with hard water, and after you have used soap in it, there is always a scum floating at the surface.

When Tap-water is warmed, Bubbles appear.—Put about half a pint of tap-water into a glass basin (a clock glass), and put it on the top of a pan of boiling water, so that it may get heated by the steam.* It will not boil, but it will slowly disappear and form steam. We do not want it to boil, because then it would spirt, and we should lose some. This experiment will take time, but I only want you to notice the beginning and the end. A minute or two after you have set the basin on the pan, you will notice a great number of little bubbles sticking to the glass, which were not there at first. What are they? Not steam, because the water is not boiling; you can easily bear a finger in it at present: it is hardly warm. They are bubbles of air. Before we heated the water the air was *dissolved*, but now it appears again in the form of bubbles. It has been found that such bubbles contain more Oxygen than air: in fact about one-third of it, instead of one-fifth, is Oxygen. This is easy to explain, because Oxygen dissolves more easily in water than Nitrogen does, so that the water does not take a fair share of each from the air.

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* The glass basin must not be allowed to prevent the escape of steam from the pan. A wedge of paper placed between the glass and the edge of the pan will allow free passage to the steam.

The Importance of dissolved Air to Animals which live in Water.—This dissolved air is of great importance to some of the animals which live in water. Fishes, for instance, live in water, and Fishes need air. They open their mouths from time to time, and take a gulp of water, passing it out through the gill-slits behind their heads. Whilst the water is passing through the gill-slits, the blood of the Fish absorbs the Oxygen, just as your blood absorbs Oxygen in your lungs. Water does not contain much air. A thousand pints of water can only dissolve about eighteen pints of air, but fortunately for the Fish, Oxygen is more soluble in water than Nitrogen, and the eighteen pints of air in water are as good as thirty of ordinary air. You will understand now why Gold-fish cannot live in a bowl of water, however well they may be fed, unless the water is changed occasionally. The Oxygen gets used up, and you might as well hope to live in an air-tight box as expect Gold-fish to live continually in the same water.

Distilling of Water.—Dissolve a teaspoonful of salt in half a pint of water; keep a little of it, and put the rest into a glass retort by means of a glass funnel. Be careful not to wet the upper part of the retort. Now fit the neck of the retort into a tall thin flask, and let a stream of cold water flow over the flask. Boil the salt water in the retort. The steam passes into the flask, which cools it and condenses it—that is, turns it into water again. Perhaps a little steam will escape, but that doesn't matter. This operation is called *distillation*. You are *distilling* water—that is, turning it into steam, passing the steam into another vessel, and turning it into water again by cooling it. When you have distilled about three-quarters of the water,

withdraw the flame, and pour the liquid from the retort into one glass basin, and that from the flask into another. Now taste the water from the flask, then some of the salt water you began with, and lastly that from the retort. What do you find? The distilled water is tasteless; that from the

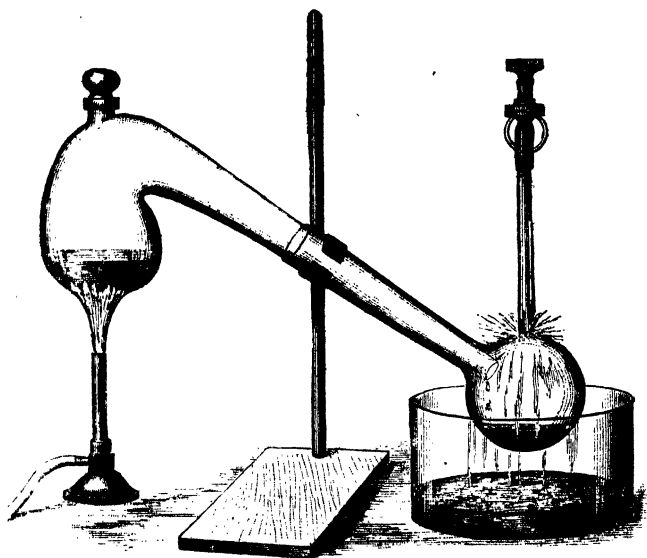


Fig. 120.—DISTILLATION OF WATER,

retort is very salt—much more so than the salt water you began with. Boiling, then, has not removed any salt; it has only removed some of the water, and the remaining portion is saltier than ever, because you have so much less water to the same quantity of salt. When solids are dissolved in water, they are generally left behind on boiling, and the steam which escapes may be cooled so as to give

pure water. You can now see how to get fresh water on board ship. All you have to do is to distil sea-water.

Distilled Water contains no Air at first.—Take a better taste of the distilled water which you have prepared. Is it not flat and unpleasant? You would not like to drink this pure water instead of that from the tap. It tastes flat chiefly because the air has been driven out of it. It has been condensed from steam, and during the boiling which produced the steam, all the air was driven off. But if you were to shake up the distilled water with air, or, better still, if you were to let it fall in a fine shower through the air, it would dissolve some air again, and would then be quite pleasant to drink.

Solids in Spring-water.—Spring-water generally contains some solid substances dissolved in it. The springs are fed by rain, which falls upon the surface of the ground, and sinks into it or flows over it, gradually collecting to form a spring or a little brook. If there is anything in the rocks or earth which the water can get at, and dissolve away, we shall find some of it in the water drawn from the spring.

Chalk dissolved in Water by the help of Carbon Dioxide.—Chalk is one of the solids often found in spring-water. Chalk does not dissolve in perfectly pure water, but it will dissolve to a small extent in water which contains Carbon Dioxide. I should like you to see this for yourselves. Make some Carbon Dioxide as we have taught you to do, and let it bubble through Lime-water till it is milky. You know that the milkiness is caused by the formation of Chalk. (See Lesson XIX.) Continue to pass Carbon Dioxide through the milky water. Before long the

milky as before. The Chalk will dissolve as soon as the water becomes charged with Carbon Dioxide. Can we make the Chalk visible again? Yes, if we drive off the Carbon Dioxide which has been taken up by the water. To do this, we will heat the water, and make it boil. The Carbon Dioxide is at once driven off, and the water turns milky as before.

Hard Water.—Carbon Dioxide is often found underground in holes and cracks, and the spring-water dissolves some of it. Water containing this gas can dissolve Chalk, and carry it away. The water has the same look and taste as common pure water, but when you try to wash with it you can soon tell that there is Chalk there. The Chalk acts on the soap, and changes it to flakes, which are of no use for washing. We call such water *Hard*, and we always try to avoid it when we want to wash ourselves or our clothes. Hard water uses up much soap, and uses it to no purpose.

Summary.—Let us now run over our Lesson on Water. We have learned that:—

1. Pure water is composed of two gases: Hydrogen and Oxygen.

2. Ordinary spring-water or tap-water contains air and a little Carbon Dioxide. The air gives a pleasant brisk taste to the water, and helps to support the life of Fishes.

3. Rain-water contains no solids, but water which has soaked into the ground contains some solid substances dissolved in it.

4. Chalk is easily dissolved in very small quantities in water that has taken up Carbon Dioxide. If the water is boiled, the Chalk is thrown down.

5. When water is distilled, all the solids are left behind. The steam from salt water can be condensed into pure water, which is good to drink, especially if it has been charged with air.

LESSON XXI.

A CANDLE-FLAME.

WANTED:—*A paraffin or composition candle, a tallow candle, a small test-tube (one inch long and a quarter of an inch wide), stout copper wire, a few bits of glass tubing, a wide-mouthed glass jar, eight or ten inches high, and some Lime-water.*

This Lesson will require at least two hours. It will be found convenient to divide it into two or even three parts, beginning the second and third parts with a short recapitulation of what has already been gone over.

A simple Subject.—To-day I wish to teach you something about a candle-flame. Perhaps you think it is hardly worth while to spend time over so simple a thing as this. We have seen candles ever since we can remember, and never found anything puzzling about them. It is when things go wrong that people begin to ask questions, but a candle hardly ever goes wrong. It never refuses to burn, and the one failing of old-fashioned candles has been got rid of—I mean the failing of wanting to be snuffed now and then. Snuffing is cutting off the top of the wick. It used to be found that although the wick gradually burned away, it did not burn fast enough, and when it grew long the candle began to smoke, and flicker, and give out a

smell. How is all that got rid of now-a-days? Three things have been done. First, candles are now made of wax that does not melt so easily as tallow. Secondly, the candles are made thicker. Lastly, the wicks are now tightly plaited, usually into a flat band. You will ask how plaiting the wick can make any difference. When a plaited wick burns it does not stand up straight, but curves outwards towards the edge of the flame, where it soon gets burnt up. I will show you before long why it burns faster in the edge of the flame than anywhere else.

Appearance of the Flame.—

Let us begin by taking a good look at the candle-flame. You see the top of the candle with its little pool of wax; then comes the wick, and then the flame. You will see a dark part of the flame close to the wick, and a large bright yellow part above. If you look very carefully you will see a faint blue layer at the bottom of the flame and on the outside. This is the inner part of an almost invisible layer, which may be followed with some difficulty right round to the top.

If you wish to see this more distinctly, take a match which has been struck and then blown out, and bring the burnt knob of the match slowly and carefully towards the edge of

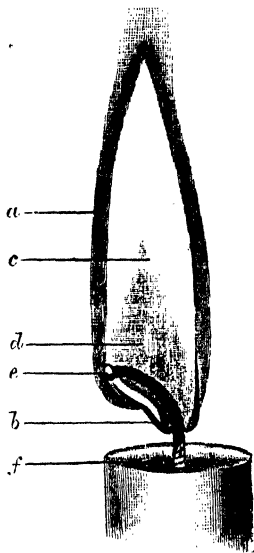


Fig. 121.—CANDLE-FLAME.

a, Outermost zone, hardly visible; b, inner portion of the

the flame. When it is about an eighth of an inch away, or less, you will see that the dim outer mantle of the flame becomes more distinct. The match-head when heated gives off something which colours it. There are therefore three chief parts in the candle-flame:—(1) a dark inner part, which we will call *the dark zone*; (2) a large, light-giving, yellow part, *the luminous zone*; and (3) a dim outer part, which is best seen at the bottom of the flame, the *outermost zone*.

Some other Flames.—Do you know of any other flames besides a candle-flame? Yes, there is a gas-flame, and the flame of a lamp. These are different in shape, but you can see that they are made up of the same parts. A gas-flame is made flat either by a slit in the burner, or by two slanting holes, which cause the gas to spread out. But if the gas is made to come out through a plain round hole, it will burn like a candle. I will fit a piece of glass tubing, drawn out to a point, to the gas-burner, and then light the gas. You see that the flame has the same shape as a candle-flame and contains the same parts.

Candle-gas.—Is it not strange that solid wax, and light, invisible gas, should burn in the very same way? Is it possible that gas is burnt in the candle-flame too? Blow out the candle, and what do you see? A stream of whitish smoke rises from the wick. It has a rather unpleasant smell. Try the effect of bringing a lighted match slowly down into this smoke. When the match is about an inch from the wick the smoke catches fire with a little puff, which is really a small explosion, and the candle is lit again. We see, then, that when a candle burns, the wax is turned into a sort of gas, which we might call candle-gas, and this takes fire when a light is put to it.

We can easily make some candle-gas merely by heating wax. Take a few chips of wax, put them into a small glass tube, held by a wire, and heat them in the flame of the candle. The wax melts and boils, and before long a sort of smoky vapour issues from the mouth of the tube. This is candle-gas. It can be lighted, when it gives a bright flame. Do you know of any other substance which, like wax, is solid when cool, melts with heat, and turns to vapour when heated still more strongly? Of course you do. Ice is turned to water, and water to steam, by heat, just as solid wax turns to melted wax, and melted wax to gas. We now see something of what takes place when a candle burns. When we first hold a light to the wick, we melt the wax on the wick and vaporise it—that is, turn it to gas. The gas takes fire, and gives out enough heat to melt and vaporise more wax, and so the thing goes on.

Use of the Wick.—There is one question which may occur to you at this point. If all that is necessary is that the wax should be turned to gas, what is the good of the wick? Why should not the wax begin to burn whenever you hold a light to it, whether there is a wick or not? If you think a moment, you will find an answer to that question. The wick draws up the melted wax little by little from the pool at the top of the candle. The wax burns slowly, just fast enough to feed the flame, and the flame is lifted well above the wax, so that it does not melt it too fast. See what happens if you hold a flame to a lump of wax. All the heat is spent in melting the wax, and the wax runs down as fast as it is melted. If you cut the wick of a candle very short, it gives a miserable little flame. Here, too, nearly all the heat is spent in melting the wax, because the flame is too close to the wax, and

hardly any gas is formed. But when you have a good long wick to begin with, covered with a thin layer of wax, your match not only melts this small quantity of wax, but turns it into gas. You get a good-sized flame almost from the first, and only just enough wax is melted at a time to fill the little cup at the top of the candle.

Wax climbs up the Wick.—How does the melted gas climb up the wick? Liquids, we know, usually run down-hill, and melted wax is no exception, as you will see if you tilt the candle. The wax trickles down the side. Well, though it is no doubt true that liquids usually run down and not up, they can be made to rise when very fine tubes or fibres are placed in them. Put the end of a piece of thread in an ink-pot, and you will see the ink run up the thread. I cannot attempt to tell you the “why” of this: it would be too hard for you at present; but it is worth while to know that fine tubes and threads do make liquids rise, even though you do not know why. Any other liquid which could wet the wick of a candle would run up it, for the wick is only a bundle of fibres. As fast as the melted wax is turned to gas, a fresh supply runs up the wick from the cup below. It is important that just the right quantity should run up, neither too much nor too little. The wick must be just big enough and the wax just hard enough. There must be enough melted wax to feed the flame, and enough flame to melt the wax, and not too much of either. If the wax is too soft or the wick too big, the wax will melt too fast and trickle down the side of the candle. This is what often happens with a common tallow candle.

Things necessary to Flame.—What are the things necessary for a candle-flame? There must be wax to be melted and vaporised; there must be a wick to carry the

melted wax up to the flame ; there must be a flame to start the burning of the gas. Anything else ? Yes ; of course air is necessary, as we saw in the Lesson on Air and burning in Air. We proved that by a little experiment, which I will repeat now, because of one little fact which we did not notice the last time.

Supply of fresh Air necessary.—I take a clean, dry glass jar, and lower this candle-end to the bottom of it by means of a wire looped at the end. The candle burns brightly inside the jar. Next I take a card, and cover the mouth of the jar with it. In about a minute the flame sinks, and very soon after it goes out altogether. I lift the card very cautiously, and take out the candle with as little disturbance as possible. I light it again and put it back into the same jar. It goes out immediately. From this you learn that fresh air is necessary for the existence of a candle-flame.

Water formed.—In making these experiments we must not forget to keep our eyes open and to note all that happens. When the card was lowered upon the mouth of the jar, the flame went out. Did you see anything else ? Yes, the sides of the jar became misty. When the card was lifted the mist soon cleared away. It was moisture—water settling on the cold glass. Where does the moisture come from ? Not from the jar, for that was clean and dry. Not from the air, for warming the air would never cause it to throw down moisture, but rather to take up more. Not from the candle, surely, for wax will not mix with water, and it is not at all likely that*the wax of the candle was damp. Here is a puzzle ! We will try to make it out by-and-by, but meanwhile do not forget that when a candle burns, water appears that was not there

to begin with. Water is formed in the burning of a candle.

Union of Candle-gas and Air.—We have now learned that candle-gas and air are both necessary to the flame of a candle. If either were taken away the flame would go out. I want to find out, if we can, something about the way in which these two things, candle-gas and air, unite to form a flame.

Heat necessary.—In the first place, you know already that they will not form a flame if they are cold. How can we prove that? By blowing out a candle. The candle-gas goes on streaming out from the wick into the air for a minute or so, but no flame is produced. Candle-gas and air are both present, but they do not form a flame because they are cool. They must be made very hot indeed before they can burn and make a flame.

In a candle-flame we should expect to find the candle-gas and the air differently mixed in different places. In the middle of the flame, where the candle-gas streams out from the wick, we should expect to find much of this gas. On the outside we should expect to find much air. Between the middle and the outside we should expect to find a place where both are fairly mixed. Let us see if this is so.

Dark Zone cooler.—I take a wooden match and hold it steadily across the middle of the flame, just above the wick. It soon gets charred, but you will see that it is most charred in two places a little distance apart, and that between these two it is scarcely charred at all. This shows us that the dark zone in the middle of the flame is comparatively cool—at any rate, not so hot as the outer part. Next I take a white card, and hold it for a few seconds

across the middle of the flame just above the wick. Look at the top of the card. You see that it is charred in a ring. This is another way of showing the same thing, that the middle of the flame is cooler than the outside.

Much Soot in luminous Zone.—Now I take a thin piece of glass tube, and hold it very steadily across the flame just above the wick. Two black rings form on the tube, and between them is a narrow clear space. What is the black stuff? We call it soot, or lamp-black. I will show you just one thing about it, and that is, that it can be made to burn away. I hold one of the black rings just above the top of the flame, very near but not in the flame. It requires some care and a steady hand to do this nicely, but you will see that when the glass tube gets quite hot the black stuff burns entirely away.

Unburnt Candle-gas in dark Zone.—Now for one more experiment. I have here a bent glass tube like a long, thin S (the upper loop of the tube should be very short). I put the upper end of this tube into the flame just above the wick, and hold it there for a minute or two. Soon we see that the tube gets filled with whitish fumes, which come pouring out at the lower end. What do these fumes remind you of? Are they not just like the smoke from the smouldering candle? Yes; and that you remember was candle-gas. The candle-gas could be lit with a match. Let us try whether the fumes which come out of the tube can be lit in the same way. See! there is a

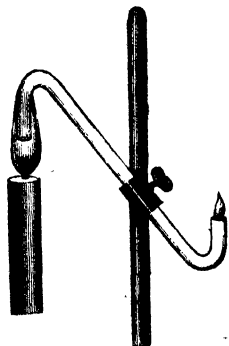


Fig. 122. — UNBURNT CANDLE-GAS REMOVED FROM THE FLAME.

small, flickering flame at the end of the tube when I have touched it with a lighted match.

None in luminous Zone.—Will the luminous zone yield us any candle-gas? I hold the upper end of the tube in it. The tube is soon coated with black soot, but no gas comes off which will catch fire.

Results obtained.—Now let us see what these experiments have taught us. We have learnt (1) that the dark zone of the flame is cool, and the luminous zone hot; (2) that the dark zone throws down no soot, while the luminous zone does; and (3) that the dark zone contains unburnt candle-gas, while the luminous zone contains none.

Yellow Light of luminous Zone.—What makes one particular part of the flame strongly luminous? There is much black soot in it, as you know, and this soot is turned to a bright yellow colour by the heat. Can you mention any other black things which turn bright yellow when heated? Yes, the poker or a piece of coal does the same thing when placed in the heart of the fire.

Faint outer Zone.—But there is still the thin, faint, outermost zone of the flame, which we must not forget. It is too small for us to experiment upon to any extent, but there are two or three things to notice about it. (1) It gives out little or no light. (2) It is very hot. You remember that we used this part of the flame to burn away the soot from the glass tube. (3) It contains no soot.

Explanation of the different Zones.—You will now be prepared to follow the explanation of the different zones of the candle-flame. Round the wick is a mass of candle-gas, distilled from the melted wax in the wick by the heat. This contains no air, and does not burn. It is therefore moderately cool, and gives out little or no light. Where

the candle-gas mixes with the air it burns. This is the luminous zone; here the flame becomes very hot, and gives out much light. Soot is separated from the candle-gas. In the outermost zone there is hardly any candle-gas, but plenty of air. Much heat is produced, but little or no light. No soot is thrown down here, but any soot brought into this part of the flame is burnt up at once.

Soot.—It is now time to ask what the Soot of the candle-flame really is. It is black, and burns away when heated strongly in air. Do you remember any other black thing which does so too? Charcoal, of course. (See Lesson XIX.) Is it possible that Soot and Charcoal are pretty much alike? Charcoal, we know, consists mainly of Carbon. Does Soot consist mainly of Carbon also?

Forms Carbon Dioxide when burnt.—We can find this out by seeing whether or not Carbon Dioxide is formed when Soot burns away in air. I will smoke a sheet of glass over the flame of a candle, then scrape off some of the Soot, and collect it in a test-tube. Then we will connect the test-tube with a bent glass tube, and dip the end of the tube into Lime-water.* When all is ready I will heat the test-tube strongly with a Bunsen burner. Now you see the Soot is red-hot, and begins to burn away. The gas bubbles up through the Lime-water, and turns it milky. This will satisfy you that the gas produced by burning Soot in air contains Carbon Dioxide, and that the Soot

* Some care is needed to make this experiment succeed. Take a test-tube of glass (not too soft), and connect to it a cork and bent tube. The end of the bent tube must pass into lime-water contained in a second test-tube. Heat the soot till it glows, without warming the air in the tube more than can be helped. Then warm the upper part of the tube, and drive the gas into the lime-water.

contains Carbon. Like Charcoal, it is mainly composed of Carbon.

Where does the Carbon come from?—It is clear that the Carbon comes from the candle, and not from the air. Does it come from the wax or from the wick? Mainly from the wax. The wick contains Carbon too, but all the Carbon contained in the wick makes but a small part of the soot which can be got from a candle. If we could spare time for the purpose, it would not be difficult to char a wick and save all the Carbon which it contains, and also to burn a candle and save all the Carbon which can be recovered in the form of soot. The soot would far exceed the Carbon of the wick.

Something besides Carbon in a Candle.—We prove clearly in this way that the candle contains Carbon, but surely it must contain something besides. The two great reasons we have for believing that there is something else in a candle besides Carbon are these:—First, if the candle were only Carbon it should burn like charcoal—that is, it should glow without flame; secondly, when a candle burns, water is produced.

There is also Hydrogen.—We must now return to this water, and try to find whence it comes. What is water made of? You know that water is made of Oxygen and Hydrogen. Where does the Oxygen come from to form the water which is produced when a candle burns? From the air, of course. And the Hydrogen? Well, the Hydrogen can only come from the candle. This seems a strange thing, that the gas Hydrogen should be contained in solid paraffin or wax, but when you remember that the solid wax is easily made into a gas in the flame, it is not so difficult to believe that candle-gas may contain Hydrogen.

Carbon and Hydrogen not merely mixed in the Candle.—We have seen that a candle contains Carbon and Hydrogen. Does it contain anything else? No: a paraffin candle contains nothing else; or at any rate it need not. The pure white waxy paraffin is made of the black substance Carbon and the gas Hydrogen. It is not a mixture in the ordinary sense of the word. You might try to mix up Carbon and Hydrogen, but you would never get paraffin; the Carbon and Hydrogen are united in what we call a *chemical* way. When two things are united *chemically* they usually make a substance quite unlike either of them. When you pour milk into water, you get something which is rather like milk, and rather like water, and you call it milky water. That is not a chemical union. But when black Carbon and Hydrogen-gas are united chemically, they may give us white paraffin wax, which is not in the least like either Carbon or Hydrogen.

Coal-gas also consists of Carbon and Hydrogen. Do you remember that we once used Coal-gas to recover a metal from its Oxide, and that we were able to do so because Coal-gas contains no Oxygen, but a substance which will unite to Oxygen when heated? That substance was Hydrogen, and the Hydrogen of the Coal-gas united with the Oxygen of the Copper scale to form water.

How the Carbon and Hydrogen burn in the Candle-flame.—Now let us go back to the candle-flame, and follow out the changes again, now that we know the composition of the thing that burns. The candle-gas or vapour consists of Carbon and Hydrogen. Both Carbon and Hydrogen burn in air when they are sufficiently hot. In the candle-gas we have both; will they burn together? Perhaps they will, if there is plenty of air; but if there is

not enough for both, the one which burns most easily may part company from the other, and burn first, and leave the other unburnt for a time until it can get enough air. Have we any proof of this? Certainly; we have found that in the yellow part of the flame there is plenty of unburnt Carbon, which becomes visible as black soot when a cold object is put into the flame. Now we have got to one great secret of the candle-flame. When the candle-gas begins to burn, the Hydrogen burns most easily, and takes most of the Oxygen, forming water. The result is that the Carbon is separated, and cannot burn at once. It gets very hot, partly because of the heat given off by the burning Hydrogen, and partly because of its own slow burning, and so it glows very brightly, and makes the candle-flame luminous. By the time the glowing Carbon gets to the outside of the flame, it has enough air to burn it up to Carbon Dioxide. The dim outer zone is simply a sheath of candle-gas burning with plenty of air, so that the Carbon and Hydrogen burn together. No soot separates, and so there is no solid to glow and produce light.

Recapitulation.—Let us just go over it all once more. In the dark inner zone of a flame the gas is unburnt; in the yellow luminous zone the Hydrogen is burnt to water, and the Carbon separates and burns slowly to Carbon Dioxide; in the dim outer zone some of the candle-gas is burning with plenty of air, and without the Carbon being separated.

Why the Wick burns away in the Edge of the Flame.—There are one or two things which I have still to explain. Why is it good to have a wick which curves over to the edge of the flame? Simply because then the end of the hot wick stands well out into the air and burns

away, as you can see by the glowing tip, instead of sticking upright into the flame where there is no Oxygen to spare for it, and where it would not therefore burn away half fast enough.

The Cause of Smoke.—When does a candle smoke? When there is a very long wick, and the candle-gas is supplied so quickly that part of the Carbon never gets hot enough to burn. Then again you get smoke when the regular supply of air is interfered with. The Carbon, which would have burnt away steadily in a free supply of air, cannot get enough Oxygen, and so passes away unburnt. If you have enough air you will never get smoke, and this is true of burning coal as well as candles. Smoke is not only a nuisance, but it is a waste, because if there had only been enough air it would have been burnt and given heat.

Putting out of the Flame.—Now let us see what happens when a candle-flame is put out. If you put an extinguisher over a candle you cut off the supply of Oxygen, without which no burning is possible. If you blow it out, the current of air cools the wick so much that there is not enough heat to convert much melted wax into vapour, and what vapour is formed is so scattered and cooled that it is not hot enough to unite with the Oxygen of the air. I will give you a very simple proof of this. Here is a short metal tube, or coil, made by winding a piece of stout copper wire round a thin pencil. See what happens when I lower the tube over the wick, taking care not to touch it with the coil. The flame goes out as soon as the wick is surrounded by the metal. Why is this? I believe it is because the cold wire withdraws the heat from the wick so fast that the wick is no longer hot enough to turn the

liquid wax rapidly into candle-gas, nor the candle-gas hot enough to burn. If we heat the coil by holding it for a minute in the upper part of the flame before we lower it about the wick, it will not have the same effect. The hot wire will remove very little heat from the neighbourhood of the wick, and so the candle-gas continues to pour forth and burn.

Carbon Dioxide in the Air. Why it does not increase.—We see that when a candle is burnt it is not “burnt up to nothing,” as people say, but that it all goes to make two gases—Carbon Dioxide and steam. All ordinary burning materials, such as oils, wax, gas, wood, coke, and coal, produce these same two things when they are burnt. In a big town tons and tons of Carbon Dioxide are sent into the air every day. This partly explains why we find Carbon Dioxide in the air. Fortunately the amount of Carbon Dioxide in air is very small, and does not get any larger, although fires are constantly burning and animals are breathing out the gas. Why is this? Is there anything which uses it up? Yes, there is. I shall have to tell you some day how the green leaves of plants do that work. They take up the Carbon Dioxide, keep the Carbon for themselves, and send back the Oxygen into the air to burn up more candles, and carry on the breathing of men and animals.

Summary.—What have we learnt from the candle-flame? The most important points are these three, but I think you will have picked up a good deal of information besides :—

1. The Candle contains Carbon and Hydrogen. When it burns these unite with the Oxygen of the air.
2. The Carbon unites with the Oxygen to form Carbon

Dioxide ; the Hydrogen unites with the Oxygen to form Water.

8. The light of the Candle is chiefly due to glowing particles of Carbon (Soot).

LESSON XXII.

CLOUDS.

WANTED :—*Glass flasks, with corks, one drawn out into a narrow neck, or with a tube fitted to it ; a spirit-lamp or Bunsen burner ; a large bowl ; some ice.*

Invisible Steam turned to Water.—I wish to show you a very simple experiment—so simple that any of you can repeat it for yourselves. Here is a clean dry glass flask. I turn it about over the flame of a spirit-lamp, or Bunsen burner, until it becomes as warm as my fingers can bear. Then I hold it for half a minute, mouth downwards, above the open neck of a second flask in which a little water is boiling. Now I cork it up tight. While I am talking to you I keep warming it over the flame. The bottle looks just as it did at first, a clear glass flask. It contains air, but it contains something else. What else ? Steam, or water-vapour. This steam is quite invisible, and looks like the air with which it is mixed. I can easily make it visible however. Here is a large bowl, into which I have put some crushed ice. I hold the flask just above the bowl for a minute or two, not allowing it to get wetted. It is merely cooled by being surrounded by cold air. Now I take it out of the bowl. The flask, which a minute ago seemed to be empty, is seen to contain water. The water

forms a multitude of little drops on the inside of the flask and dims the glass. If I heat the flask again, the drops will disappear, but they will come back as often as it is cooled.

This experiment, which is so simple that you perhaps think it too childish, shows us two things :—

1. Water may be present in the form of vapour or steam, when we cannot see it.

2. Hot air can hold or carry more water than cold air. When the flask and the air inside it are hot, the water is held up, and becomes invisible steam, or water-vapour. But when the air inside the flask becomes cooler, some of the water is dropped, or *condensed*, and forms a mist on the sides of the flask.

The invisible Steam in the Room turned to Water.—Now let me show you a second experiment almost as easy to understand as the first. I have here a second clean, dry flask, I pour some ice-cold water into it, which has been chilled by the lump of ice which still floats on the surface. Almost at once a mist forms on the outside of the flask, and in a minute or two this mist thickens into drops of water. By-and-by the water will run down the sides of the flask. Where does the water come from? It must have been present as invisible vapour in the air of the room. The cold water in the flask condensed it, and it formed drops on the outside of the flask. Have you ever seen water-vapour condensed in this way before? No doubt you have breathed on the window-pane, and formed a misty film of small drops. You have seen a mist of the same kind form on your bedroom window in cold weather, or on the window of a room where a number of people have been shut up. The cold outside air chills the glass,

and the glass chills the vapour in the air of the room, and condenses it into drops. Any room which contains a number of people is sure to have a great deal of water-vapour in it, for they breathe it out from their lungs. But whether there are people in the room or not, there is enough water-vapour in the air to condense upon an ice-cold object.

White Cloud.—Perhaps all of you did not know before that water-vapour or steam is perfectly invisible. We talk of the clouds of white *steam* which issue from the funnel of a locomotive engine. It is not properly *steam* at all. It was steam so long as it was inside the hot funnel, but as soon as it came into the cool air outside it condensed into very small drops of water, and these drops were for a short time carried or suspended in the air. I cannot explain why this cloud which issues from the funnel looks white until you know more about light, but you will learn some day that it would not be white at all if it did not contain vast numbers of drops or specks of some kind.

Mist before the Mouth.—On a cold winter's day you can see a mist before your mouth. The hot air breathed out from your lungs is chilled as soon as it meets the cold air, and all its vapour condenses in a moment into millions of minute drops of water, which dry up and disappear directly.

What Clouds are made of.—The clouds which float in the sky are like the clouds which come out of the locomotive. They are made up of little drops of water, so small that even if you were in the midst of the cloud you could not see them. But you would feel them against your face and hands, and they would make your clothes

damp. We have reason to believe that the upper clouds, high in the sky, consist, not of small drops of water, but of particles of ice.

Cloud on a Hill-top.—I daresay you have all been inside a cloud some time or other. When we go up a high hill, a mist sometimes surrounds us, so thick that we can only see a few steps before us. Then we feel cold, because our faces are chilled by the water. After a time our clothes are covered with dew. If someone else were looking at the same hill-top from a great distance, he would see a cloud resting upon it.

Cloud in a Valley.—We need not even go up a hill to get into a cloud. Sometimes the clouds form in the valleys and plains. At such times we say that there is a mist over the ground, for we cannot see far before us. The air feels cold, and our clothes are wetted with dew. There may be a mist in the valleys when it is clear on the hill-tops. The shepherd minding his sheep on the hills sees the sun shine bright, and all the trees and rocks are quite distinct. But down in the bottom of the valley rolling white clouds appear.

I will now try to explain why clouds form sometimes on the tops of the hills, and at other times in the bottom of the valleys.

Clouds on Hill-tops.—All clouds are formed by the cooling of steam or invisible water-vapour. Suppose that a current of warm air blows over the sea. It will pick up a good deal of water-vapour, for the sea is always giving off vapour. The air will move off and carry the vapour with it. If this current of air strikes against something cold, the vapour will condense into a multitude of tiny drops, or what we call a cloud. The cold object which the

current meets may be a hill. If so, the cloud will form around the hill.

What becomes of Clouds.—A cloud does not remain long without change. In a little while one of two things is sure to happen. Either the little drops will run together, and form big drops which fall to the ground as rain, or they will melt away into invisible vapour.

Rising Column of moist Air.—What will happen if a current of warm air, carrying plenty of invisible vapour, rises steadily up from the surface of the earth? It is easy to see that it will lose its heat by meeting with cold air at a great height above the ground. Then the vapour will condense and form a cloud. The current will be quite invisible near the earth, but it will become quite visible when it reaches the colder air at a great height. We often see this in hot summer weather. The sun warms up the earth, and this warms the air next above it. The warmed air *expands* and becomes *less dense* (do you remember what these words mean?) and rises. At last it reaches a layer of cold air, which checks its upward movement, and cools it, and causes its water-vapour to condense into one of those great white *woolpack clouds* which are often seen in the sky in summer. The woolpack clouds are often flat below, because there is a clean line of separation between the warm and the cold air, and the visible cloud forms suddenly the moment that the cold layer is reached.

Rises over Land more easily than over Sea.—When the sun has been shining for some hours on the land, the land becomes warm, and currents of warm air rise from it. Much more time is required to warm up the sea. Why is this? Because water has a much greater

capacity for heat than rocks and earth. It takes longer to warm, and longer to cool. If the sun shines equally, and at the same time, on land and sea, the land will send up columns of warm moist air, which will give up their heat, and condense their vapour, when they reach a certain height, and form great masses of woolpack clouds. This is not so easily done over the sea, which remains cold for a



Fig. 123.—WOOLPACK CLOUDS.

long time, and does not send up columns of heated air so readily.

An Example.—One beautiful summer day I was sailing round the Isle of Man. We could see the mountains of the island close at hand; and in the distance were the mountains of Cumberland, and Galloway, and Antrim, and County Down, and North Wales. Most of these were too far off to be seen themselves; but over all of them were great piled-up clouds which could be seen a hundred miles off. They had the rounded cauliflower or woolpack shape above, and a flat base. There were no clouds over the sea, but the sun shone fiercely in a blue sky. Columns of moist air were rising all day from the land, and forming

new clouds, but no columns of air rose from the sea, because it did not warm up fast enough. It is true that moist air was rising from the sea all the time, but it rose much more gradually and gently. As evening came on the land cooled, the columns of air ceased to rise over the hills, and the clouds gradually melted away.

Chilling of Air by Expansion.—I will now show another experiment which I cannot fully explain to you at present. I think you will understand something about it, though you will not understand it perfectly. Here is a flask with a long narrow neck. The flask is nearly empty, but you can see a few drops of water in it. It was first filled with water, and then turned upside-down. I put the neck of the flask to my mouth, and suck out the air as hard as I can. Those who are quite close will see a faint cloud form in the flask when I suck. You might be inclined to think from the look of the glass that I was blowing into the flask, instead of sucking air out of it. If we had an air-pump at hand, I could show the same thing more plainly by exhausting the air from the flask with a few turns of the handle. But you have seen enough to convince you that when some of the air is removed from a vessel, a faint cloud forms. Part of the air was suddenly sucked out, and the rest of the air expanded to fill the empty space. Whenever air expands, or spreads itself out, it becomes chilled. This is the part of the story which I cannot explain fully to you at present. We must wait till you have grown older and learnt more. But though you do not know why the air is chilled by being expanded, you know why the chilled air produces a cloud. The water-vapour in the flask is condensed by cold, and runs into little drops of water.

Moist Air, chilled by Expansion, forms Cloud.—

This is important, because the same thing takes place on a large scale in Nature. The air which begins to rise from the surface of the earth expands, or spreads out, as it rises. Why does it expand? Because it has less weight pressing upon it. The air has weight, and presses downwards. At the surface of the earth the air has to bear the weight of all the air above. It is like the bottom book in this pile of books, which has to bear the weight of all the rest. But as the air ascends, it has less and less air above it. Its load is lightened, and it expands, or spreads out. As it expands, it is chilled (remember that you do not know *why* it is chilled). As it is chilled, its vapour becomes condensed, and forms cloud.

The expansion of the air as it moves away from the surface of the earth is one cause of the coldness of the higher regions of the air, and it is one cause of the formation of clouds.

Moist Winds form Clouds about Hills.—A current of warm air blowing over the sea will carry much vapour. Most of the winds which blow across our islands are of this sort. They must blow across the sea, or they could not reach us at all, and they generally blow from the south-west. This means that they blow from warmer regions, and across the wide Atlantic. The south-westerly winds generally drop a great deal of their vapour in the form of rain as soon as they reach our shores. There are three reasons for this:—

1. They blow from the south-west, and are always passing to colder and colder regions.

2. The land is generally hilly, and much higher than the level of the sea, so that the winds are forced to rise

into the colder regions of the air as soon as they reach the hills.

3. The hills are cold objects during most of the year, and most of the day.

You will understand, I hope, that winds blowing across the Atlantic are pretty sure to be chilled when they reach these islands, especially when they blow against our hills. It is only when the sun is shining brightly on the land, or when the land is warmer than usual, that the moist wind can escape being chilled. What will happen when the winds are chilled? They will be unable to carry all the water-vapour which they have taken up; a good deal of it will be condensed and form rain.

How Clouds form in the Bottoms of Valleys.—It is harder to explain why cloud or mist forms at times in the bottom of a valley and not on the hills. When this happens, it is because the air of the valley contains more vapour than the air over the hills, or is more rapidly cooled.

Valleys are often wetter than hill-tops. Water collects in the valleys, and forms streams or marshes. This water may be at the moment warmer than the air; for air warms and cools very fast, while water warms and cools more slowly. You remember that in Lesson XVII. you were told that water has a greater *Capacity for Heat* than any other common substance. If the water is at the moment warmer than the air above it, it will give off more vapour than the air can carry, and some will condense as mist or cloud. In frosty weather mists often form over streams in this way.

In still weather, cold air, which is denser than warm air, sometimes settles to the bottom of the valleys. On a

summer evening, after the sun has set, a cold current may sometimes be seen or felt creeping down the hill-sides. If such a current mixes with air which is loaded with moisture, some of the moisture will probably condense into cloud or mist.

Travels of a Drop of Water.—Let us follow one of the particles of water in its travels. We will begin with a drop of water at the surface of the Atlantic, hundreds of miles away. The hot sun turns it into vapour, and the warm air drinks it up. It is swept gently along over the sea until it reaches the shores of our island. The wind drifts over the low sandy lands near the sea, and then strikes against the hills a few miles inland. Now it is forced to flow up the slope till it rises several hundred feet above the sea. It is chilled by rising into the colder regions of the air, it is chilled by expanding, and it is further chilled by the cold hill-sides. The moisture condenses, and our particle of water, which has floated along so far in the form of invisible vapour, now turns to a little drop. The wind bears this and vast multitudes of other drops along with it in the form of great fleecy clouds. Gradually the drops begin to run together, and form larger drops, and at last these fall to the ground as rain. They soak into the earth, trickle through bogs and wet pastures, and at length run together into a little thread, which joins others, and forms a small stream. Many streams collect, and at last a river is made, which flows down to the sea, bearing with it the drop of water whose wanderings we are trying to follow. It has now made its way back to the ocean from which it started.

Circulation of Water.—There is, as you see, a regular circulation of water up and down, from the sea to the air

and back again from the air to the sea. The water circles, or moves round and round. Some power is needed to keep it moving. What is this power? The heat of the sun.

LESSON XXIII.

THE HISTORY OF A SUMMER SHOWER.

The Shower.—A bright, sunny morning! Those who are out of doors in good time see the sun shining for hours together in a clear sky. The air is almost still.

When the sun has risen some five or six hours, and is tolerably high in the heavens, clouds begin to gather. Overhead they seem to be dark masses of no particular shape, but when we see them nearer to the horizon, in side-view, they look like cauliflowers or piles of wool, bulging out into irregular rounded lobes. Some have a flat base, as if they had been cut off clean below.

The sun shines upon the edges of many of these piled-up clouds, and turns them to white and gold; others are in deep shade, and show inky colours. The air begins to be hot and oppressive. Puffs of wind drive the dust this way and that, and the clouds are moving in different directions at the same time. It is now past noon. The sun is quite hidden, and an unnatural darkness comes on. One quarter of the sky, to the south-west, is tinged with dusky yellow, while the opposite quarter has the colour of lead.

Candles are lit in houses, and the people in the road mend their pace, now and then glancing round at the threatening sky, which promises a shower before long. The pavement is spotted with big drops. Then there is a pause.

The rain begins again; it is in earnest this time. Did you see that flash of lightning? The thunder follows close behind! The wind has risen, and slants the falling rain. The trees turn up the white side of their leaves, and their branches quiver and groan. All the 'gutters are choked, and the road, where it climbs the hill-side, is one wide stream. Light is beginning to break through on that side of the sky which was just now amber-yellow. Yes, it is brighter now, and we can blow out the candles. But the rain still falls as hard as ever. At the bottom of the garden is a pool big enough for a duck to swim in. There! that is the last of the downpour. A gleam of bright light appears in the south-west; the wet leaves glitter. Every moment it grows brighter, and now we see the clouds plainly, with no gloomy film between us and them, as there was a few minutes ago. Half the sky is covered with little clouds of light-grey colour. They seem to have been caught on a sudden by a breeze from a fresh quarter. The piled-up masses are gone, and we have waves of dappled grey in place of them. But stay! the piled-up clouds are not gone altogether. I can see a great bank of them far away to the north-east, growing plainer and plainer as the sky clears. There is a faint flash in that quarter now and then, followed by a rumble of thunder. Now we see the first gleam of real sunshine. It does not last, but there will be more by-and-by. The wind blows fresh, and it blows towards the north-east, on the heels of the storm.

At last there is a patch of blue sky, and the sun shines bright on the edges of the clouds. The retreating cloud-regiments take all colours. How they tower up into the sky, rank above rank! They are far away by this time,

but how high they seem! The thunder-cloud must be some miles thick.

The storm is past. The hot sun dries the leaves. The birds begin to chirp and twitter. The torrents slacken. Let us walk out, and enjoy the fresh breeze. How different from the sultry heat of the last few hours! Let us look at the rain-gauge. It has been a smart shower, for I see that more than an inch of rain has fallen in three-quarters of an hour.

I will tell you as well as I can what takes place in a summer shower, but you must not be surprised if we come across some difficulties which cannot be made quite plain to young people. There are some questions about this morning's shower which I cannot answer, and I am not sure that anyone can.

How the Clouds formed.—The first thing that happened was that the sun began to warm the earth. Then the earth warmed the air above it, and the water on the surface of the ground turned to vapour. The ground seemed quite dry at breakfast-time, and you remember that we noticed how dry and brown the grass-plot was. But even in hot weather there is a good deal of water in the ground, which rises little by little from the damp gravel and clay far below the surface. A hot sun can always raise water, at least in England.

Their Shape.—As the air and water-vapour grew warm they became *less dense*. Do you remember the little experiment which we made to show what happens when air is warmed (p. 190)? Then of course they began to rise. If we could have seen what was going on, we should have seen a column several miles high, with a fantastic top of the kind called *woolpack* or *cauliflower*. The top of this column we

did see, because in the upper regions of the air the vapour was condensed by the cold, and turned to visible cloud. Why is the top of the column colder than the bottom? First, because the upper layers of the atmosphere radiate or give out their heat more rapidly into space. They have only a thin blanket over them, and they cool fast. The lower layers are screened by the upper ones; they have a thicker blanket over them, and cool slower. The blanket, of course, is the atmosphere itself, which keeps in the heat.

You will recollect that some of the woolpack clouds had a flat base. That shows us that, in some places at least, there was a sudden passage from warm air to cold. Below the line the air was warmer, and the vapour was not condensed. Above the line the air became suddenly much colder, and the vapour was condensed into multitudes of minute drops of water. There is another reason why the top of the column was cooled. The air and vapour, as they rise, have less and less weight laid upon them. At the surface of the earth they are weighted with the whole atmosphere, but as they rise they leave more and more of the atmosphere behind them. On this account they are at liberty to expand more and more. They do expand, and the act of expansion chills them. You remember that when we sucked air out of a bottle the vapour at once expanded, became cool in doing so, and formed a thin mist.

Why the Sky became dark.—The heat of the sun continued to send up columns of vapour, until at last a very dense cloud was collected, so big and so thick that it shut out much of the sun's light. Then we had to burn candles. The sunbeams which struggled through the roof of cloud took an amber colour. When the cloud was seen with the light falling on it, it looked lead-coloured. Here is a sheet

of orange glass. I put a piece of blue cloth behind it, and it looks dull and nearly black. I hold it up to the window, and the light which comes through is yellow. In the same way a very dense cloud looks dark when it has a dark background, and when we look at it from the same side as that on which the light falls; but it looks yellow when it is between us and the light.

Clouds turned to Rain.—When enough vapour had condensed to form a very thick cloud, the minute drops of water began to run together and form bigger ones. These now fell very slowly towards the earth. As they fell, they hit against other drops, which mingled with them, and made them bigger. After falling through a mile or two of dense cloud, they were big enough to spot the pavement with circles an inch across.

Why big Drops fall faster than little ones.—Do you understand, I wonder, why big drops fall faster than little ones? It is because they offer less surface to the air in proportion to their weight than little drops. Suppose we had a marble an inch in diameter. Eight marbles, each half an inch in diameter, would weigh just as much. The surfaces of the eight marbles, if measured carefully, would add up to twice as many square inches as are contained in the surface of the large marble. When you are older, you will learn to prove by calculation that this is exactly true, but I can help you to see it by means of a model. Here is a large sheet of white paper, cut into gores. The gores can be fitted together, so as to cover a large ball very fairly.

I have also a smaller sheet of black paper, cut into the same number of gores, each of which is just half the height and half the width of the white ones. The black gores can

be fitted together, so as to cover a ball half the diameter of the large one. Now when I lay the black paper over the white one, you can see for yourselves that the black gores cover half of the white ones which they touch, and that they only touch half of the white gores at all. That is to say, the black paper is exactly one-fourth of the size of the white paper. Eight black papers exactly like this one would cover just twice as much surface as one white paper.

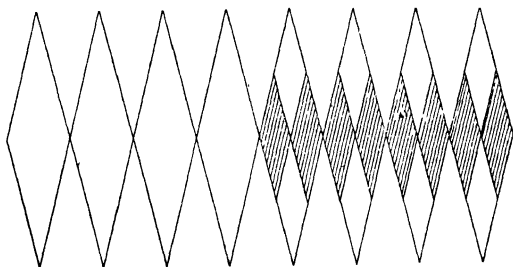


Fig. 124.—HOW TO MAKE THE MODEL. GORES OF WHITE AND BLACK PAPER.

Now eight black papers would cover eight small balls, each half the diameter of the large ball, which could be covered by the white paper. The eight small balls would weigh just as much as the single large one.

So you see that if eight little drops of water run together to form one large one, they reduce the surface offered to the air by one-half.

[A wood-turner will readily make a large ball, and eight small ones of half its diameter. Paper gores can then be cut to fit each size of ball. The circumference of the large ball, measured with a string, gives the length for the gores. Half the circumference gives the height. Measure this space out on white paper, and

divide it into any even number of gores, as in the figure. Mark out the black gores in precisely the same way, keeping the same number, but halving each dimension. A common balance will show that the eight small balls weigh as much as the one large one. The sheets of paper show that they expose twice as much surface.]

Now the more surface any body exposes to the air in proportion to its weight, the more slowly it will fall through the air. Bits of paper or feathers fall very slowly, because they expose so much surface in proportion to their weight.

I have here two sheets of paper of the same size. One I squeeze into a hard round pellet, while I leave the other flat and smooth. I hold both of them high in the air, one in each hand, and let them drop at the same instant. The crushed-up paper falls to the ground long before the other. Both are of the same weight, but one exposes much more surface than the other.

If we could divide a drop of water into eight little drops, they would expose twice as much surface, and would fall more slowly in consequence. If we were again to divide each of the little drops into eight, we should double the surface again. By repeating the operation till we reached a size so small that the drops could not be seen by any microscope, we should get drops which would not fall a foot in an hour, and the drops of water in a cloud are as small as these. But when they run together, they form big drops, each perhaps weighing as much as some millions of the little ones, and these big drops fall very fast indeed.

[Here a sharp pupil may recollect the famous experiment of Galileo on falling bodies, and ask why a big stone falls to the ground in the same time as a little stone, if a big drop of water falls faster than a little drop. It may be explained that a stone of half a pound

weighs several thousand times as much as any raindrop. The weight is so large that, compared with it, the resistance of the air goes for nothing, and an increase or decrease in the surface no longer counts.

Winds set up.—While the column of air and vapour was rising into the sky and spreading out above, air was

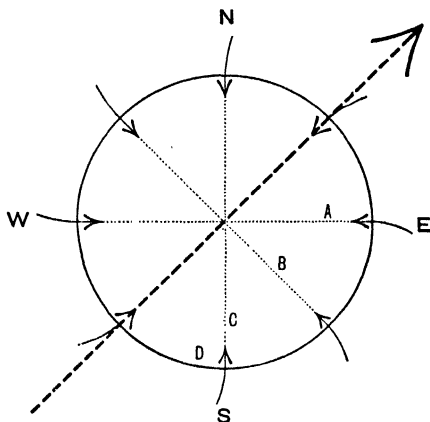


Fig. 125.—DIAGRAM OF A STORM.

sucked inwards from all sides. The light winds which blew during the morning were probably caused by this indraught of air. The air would not move quite straight to the column, any more than the water in a bath moves straight to the waste-pipe in the bottom when the plug is lifted. It would be sure to get a twist, and to move round and round in an eddy.

Diagram of a Storm.—The ascending column is set spinning in consequence, like a top on its peg, though very slowly. It does not keep fixed to one place, but travels

along, as the spinning top often does. All our big storms travel pretty much in the same direction—that is, from south-west to north-east. The little storms, such as our summer showers, are not so regular in their course. I show you here a diagram of a storm, which happens to be like that of this day.

The storm travels in the direction of the big arrow (S.W. to N.E.). The winds blow inwards from all sides in the direction of the small arrows. Suppose that you kept still in one place and watched the storm, and let us further suppose that the part of the storm marked A on the storm-chart be exactly overhead at first. As the storm drifted along to the north-east, B would come overhead, then C, and then D. Now the chart shows you that the wind will blow from the east when A is overhead; from the south-east when B is overhead; from the south when C is overhead; and from the south-west when D is overhead. To anyone who keeps still while the storm travels over him, the wind will appear to veer, blowing from different quarters one after another, though the wind really goes on circling in the same direction, as the storm travels along.

LESSON XXIV.

THE COURSE OF A RIVER.

The purposes of the Lesson have required some changes (chiefly omissions) of little importance, but nearly everything that is said of this river will be found to be true of the Tees.

Choice of a River.—There is a river in the north of England which is more beautiful in my eyes than any other stream that flows. I do not mean to say that everybody would admire it quite as much as I do. It is because I have spent many a summer holiday on its banks that I prefer it to all others. Let me tell you what is to be seen along its course. We will begin at the sea, and follow it up to its source among the hills.

Mouth of the River.—The mouth of this river is a wide frith of salt water. Ships sail upon it, and many a collier may be seen steaming in or out. The smoke of great ironworks rises here and there from the banks. Plains of sand are spread out in some places; in others there are mud-flats or salt-marshes. Hills are to be seen at no great distance, and one of these, a high hill on the south, commands a view of all the country for miles round.

The estuary narrows very fast as we follow it inland. Where it is widest, you can hardly make out anything on the opposite shore except hills and the smoke of an occasional colliery or blast-furnace. Five miles higher up you can distinctly see a man walking on the other side. Another five miles, and the river, though still a tidal stream, deep enough to float a sea-going steamer, is so narrow that you can read the names painted on the houses of business across

the water. Then comes the first bridge, above which the river can only be navigated by small craft.

Tributaries.—Many tributary streams of good size flow into the main river, and these are fed by countless brooks and rills. A map of the whole valley looks like a tree with all its branches and twigs.

A Weir.—As we go on ascending the river, we pass through a wide and fertile valley, dotted over with towns and villages. There are woods and plantations, meadows and cornfields, church towers and country houses. Before long we come to a weir, the first of many weirs, built across the river, with a mill hard by. We are now about twenty miles from the open sea. The weir is very strong, and built of large stones. It has sloping sides; one of them looks up-stream, and is always under water, while the other is at times nearly dry. What is the use of a weir? To pond up the water, so that it can be made to turn a big wheel. There is a sluice to run the water past the wheel when the mill is at work. Why is the weir so much broader below than at the top? In order that it may be as strong as possible. If it were not very strong, it would be swept away by the first winter flood. Why does the weir slant across the river? If it ran straight across it might be made ever so much shorter. Yes; but then it would not allow the water to escape over the top so easily. The longer the weir, the more room there is for the water to pass. This is very important when the river is flooded by heavy rains. A long weir is like a wide door, and gives free passage to the flood-water. •

The River-plain and the Hills.—The river is here flowing through a wide, flat plain. When you look across this plain, you get no true notion of its real size. The

hills seem near and of a good height. They are really five or six miles away from the river on either side, and some of them are from 300 to 500 feet above the plain. A rise of 500 feet in five miles is not so much as it looks at first sight, though it is respectable for so flat a country as England. Let us measure it out on paper. A mile contains 5,280 feet; and ten miles, which we will take as the whole width of the valley at this point, is 52,800 feet. 500 feet are to 52,800 feet as 1 is to 105. Let us draw the valley on paper of its true proportions. If you make the valley six inches wide, the hills will only be one-seventeenth of an inch high. Let us make our section ever so much bigger. I will draw it on the black-board, and make the river valley a yard wide. Still the hills only rise to one-third of an inch. How absurdly flat the valley looks! Yet it is by no means flat when compared with other large valleys near the sea. The Thames valley below London is flatter still. Even if the valley had been only two miles wide, and the hills of the same height as now, it would have looked very flat on paper. The rise would be only about one-third of an inch in six inches, or an inch and two-thirds in a yard. But that would be a valley with fairly steep sides. If you had looked at this or any other valley, and then drawn its slopes according to your own impression, you would have made it much steeper than it really is. A slope seems to us steeper than it is, because we get a fair notion of its height, but not of its length. The whole length is not properly spread out before us; we see it *fore-shortened*, like a telescope held to the eye. If we were to go up in a balloon, we should be better able to judge of the width of the valley, but then we should not be able to judge of the height of the hills.

Why is the Valley so wide?—Why should the valley be so much wider than the stream which flows along it? The river is quite out of proportion to the valley, which is several hundred times as wide. We will try to answer this question a little later on.

River Shingle.—What is this wide flat plain made of? I think I can tell you something about it, for not long ago I saw a large gravel-pit a mile or so from the river, where men were busy carting pebbles and sand. You have only to walk a short distance by the river to see that its banks are made of clay, and mud, and sand, with rounded pebbles of all sizes. How did these things get there? It is easier to trace the pebbles than the rest of the materials. I have gathered scores of them to see what they were made of. There were pebbles of limestone, and sandstone, and a hard, dark-coloured volcanic rock, called Basalt. I never found a single pebble of granite or slate. If the pebbles had been washed there by the sea there would have been plenty of both, for the shingle on the sea-shore, only a few miles away, travels steadily southward, and contains many pebbles of granite, and slate, and other rocks from distant parts of the coast. There are none such here, but only bits of rocks which occur in this very valley. It looks as if the pebbles had come down the valley, and had been borne along by the river. But how could the river carry pebbles weighing many pounds, or even half a pound? A stone of anything like that size would surely drop to the bottom. It would drop to the bottom, but it would not stick there. It would be rolled along. Very big pebbles can be rolled along the bed of a stream in flood. I once saw big stones swept down a river like straws. It was in a rather narrow channel, not far from the top of a

waterfall. I wanted to plant a stone to rest my foot on in crossing, and I brought the biggest stones I could lift. But it was quite in vain! One after another they were trundled along, and went over the fall. During floods very coarse shingle is swept down by torrents. I have seen a valley strewn with pebbles, many of them as big as my head. A week before, not a pebble was to be seen beyond the banks of the river. All was grass and hedges. But heavy rain came on. The river rose, swept away its bridges, and devastated the fields with shingle. Great banks of pebbles, large and small, lay piled upon the meadows, and rose in one place to the top of a wall which had managed to resist the fury of the torrent.

You must remember that things do not sink so readily in water as they do in air. A stone loses from one-half to one-third of its weight merely by being placed in water.

Bends of the River.—I have brought a map of the lower part of the river to show you. It is a very careful and accurate map, made by the Ordnance Survey. Look at the course of the river. How very crooked it is! Do you see that nearly all the bends are rounded? The river seldom changes its course suddenly, but forms loops. Why does it bend so often, and form loops of horse-shoe form? You must watch a river for a few minutes in order to answer that question. I should advise you to choose a stream which is not very wide or deep, but fairly rapid. Look out for a sharp bend. You will find that the great rush of water is on the *outer* side of the bend, and that here the stream is deepest. On the *inner* side, the current is not so rapid, and the water is shallow. If the bend is very sharp, and the stream flows fast, you will be able to see a thing which you would hardly have expected, and that is, that

the surface of the water is higher on the outer side, and slopes gently towards the inner side. I can show you the same thing more plainly in a bowl of water. I put my hand into the water and move it round and round, so as to make the water circle pretty fast. Now you see that we have set up a tolerable whirlpool, and the water rises ever so much higher on the outside of the whirlpool than in the centre. Next I drop some fine sand into the bowl. You

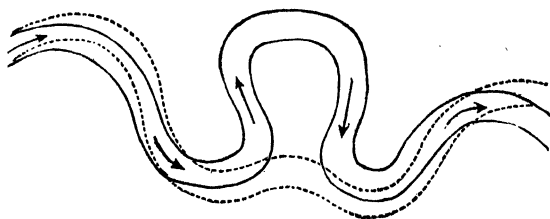


Fig. 126.—DIAGRAM SHOWING HOW A RIVER GRADUALLY SHIFTS ITS BED.

The dotted line shows the new channel.

see that it is quickly swept out of the swift current towards the inside, and collects towards the centre. In the brook, the sand and small pebbles are swept in the same manner away from the outer, and towards the inner side of the bend. This goes on day after day, and week after week, until the brook shifts its place. The outer side of every bend has been steadily scooping out, and the inner side has been piling up, and now the bend has grown larger, and makes a wider sweep. Sometimes two bends, on opposite sides of the same loop, work towards each other, until they meet. The water then flows through the new and shorter cut, and the loop is deserted. In flat valleys with winding streams such deserted loops can often be seen half-full of

water, or dry and grass-grown. The river never ceases shifting its course, and thus it travels from side to side over the whole width of the valley.

Widening of the Valley.—This shifting from side to side and the turning over of the loose stuff in the bed of the river mean continual wearing down of the shingle, and gravel, and sand, and even of the rocky channel itself. Rough blocks lose their sharp corners and become rounded. Big round pebbles grate over one another, and grow smaller by degrees. Small pebbles are turned into fine sand, and swept down the stream. The river is something like a slack rope which is always twisting round. It wears a wide groove for itself, far wider than it ever fills, and if you give it plenty of time it will go on widening its channel to any extent. But most of the width of the channel is pretty sure to be choked with pebbles, and sand, and clay. I have tried to answer the question which we put a little while ago—Why is the valley so much wider than the stream which flows along it? I hope you understand the explanation.

The Work of the River.—The river goes on grinding and grinding without pause. When in flood it grinds fast; when the water is low it grinds slowly, but it never stops grinding so long as the water flows at all. You can see the result if you look at the muddy water of a great river where it enters the sea. All that mud has been ground up by the river and its tributaries. Some great rivers carry a million tons of fine mud out to sea every day.

The River among the Hills.—But we must be getting on, or we shall not reach the sources of the river to-day. Let us take the railway, and skip over the next

twenty miles or so. When we leave the train, we find ourselves among the hills. The river no longer flows in a wide plain, but in a narrow gorge with rocky sides, and a rocky bed. Low cliffs, overgrown with honeysuckle and ivy, are washed by the stream. Woods of ash and young oak clothe the banks. The mail-road which runs by the side of the river rises and falls continually; in one place it is almost level with the water; in another it is a hundred

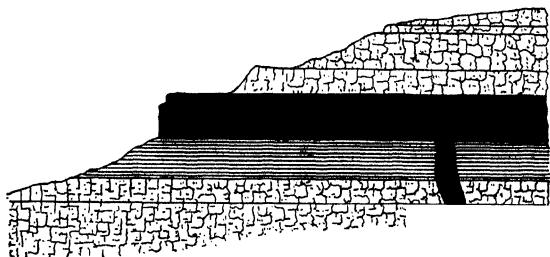


Fig. 127.—BASALT LYING AMONG BEDS OF LIMESTONE AND SHALE.

feet above it. The stream has changed its note. Lower down it glides with, at most, a gentle rippling sound, but here it rattles and roars over its stony bed. Two or three miles take us through the gorge, and then the valley opens out again. We see in the distance a town, with its bridge and ruined castle. Beyond the town we enter another gorge, whose sides are planted with woods. Mile after mile we follow the winding stream. In one place we come to a steep cliff, bared by the river, which flows at its foot. The bank has given way, and much of it has been swept down the valley. You see how the trees slope this way and that. Some are broken, some lie on the ground. Then we come to a point where the whole bank

has been carried away. A great face of clay and earth rises sheer out of the deep water. Notice that here again it is the *concave* side of the bend that wastes and crumbles. We must climb by the side of the cliff, and make our way across the fields at the top. Once up the steep slope, we find to our surprise the flat floor of a wide outer valley, out of which the gorge has been cut.

A Moorland Valley.—Still we ascend! We are now forty miles from the sea in a straight line, and, I suppose, four times as far along the bends of the river. The scenery changes once more. Now we see steep and bare hill-sides, stretching mile after mile, and rising a thousand feet and more above the sea.

Basalt.—A thick bed of the volcanic rock called Basalt runs through these hills. You may remember that pebbles of this rock are found in the river-gravel all the way down to the sea. Once this Basalt was fluid, and intensely hot. It was pumped up from below, and forced by the pressure of imprisoned steam into any crevice that it could find. It squeezed in between the beds of rock, which then lay far beneath the surface of the ground, and lifted the whole weight until it formed a huge cake many miles wide, and more than two hundred feet thick in places. Slowly it lost its heat, and gave off its steam, and hardened into black rock. The rocks above and below it still show signs of the baking they got when this white-hot stuff was squeezed in between them.

The wasting of the hills by countless brooks, which flow sooner or later into the main river, has at length brought the Basalt to the light of day, and a climb up the hill-side, or a walk of a few miles up the valley, will bring us to a spot where we can see it close at hand. Basalt is

far harder than the limestones, and sandstones, and shales, which are found above and below it. It *weathers* differently. When it has been long exposed to rain and frost, it does not split up, as they do, into horizontal layers, but into upright blocks. These are of all sizes and shapes, three-cornered, four, five, or six-cornered, with flat sides. No doubt you have seen pictures of Fingal's Cave in Staffa, or of the Giant's Causeway in Antrim. The rock in these places is Basalt too, and forms columns far more regular than any to be seen here.

The Gorge.—As we look around we see that the Basalt stands out like a ledge from most of the hill-sides, and then drops suddenly in a step or cliff. At the foot of the cliff is a great heap of tumbled stones. The cliff of Basalt does not run straight across the valley. In the middle, where the stream is always flowing, the gorge has been worn much farther back than on the sides of the valley, where much of the Basalt is still left. If you were to put a slice of cheese between two slices of bread, and cut a sloping notch through the pile, you would see a **V** of cheese in the notch, like the **V** of Basalt in this valley.

The Waterfall.—Next we have to walk along a winding glen, planted with trees, to reach a waterfall, whose sound can be heard some minutes before we see it. At last it comes suddenly into full view, one great sheet of water, tumbling over a cliff seventy feet high, into a deep pool. Here at last we have found the stream in the act of cutting through this stubborn rock. The running water slowly wears down the Basalt, but the pebbles and grit borne along by the river wear it down still more. Now and then a block is loosened from the cliff, and falls at once. You can see many such lying in and around the pool. Under

the Basalt is a bed of softer rock, which is always being undermined, and this helps to keep the cliff vertical. If

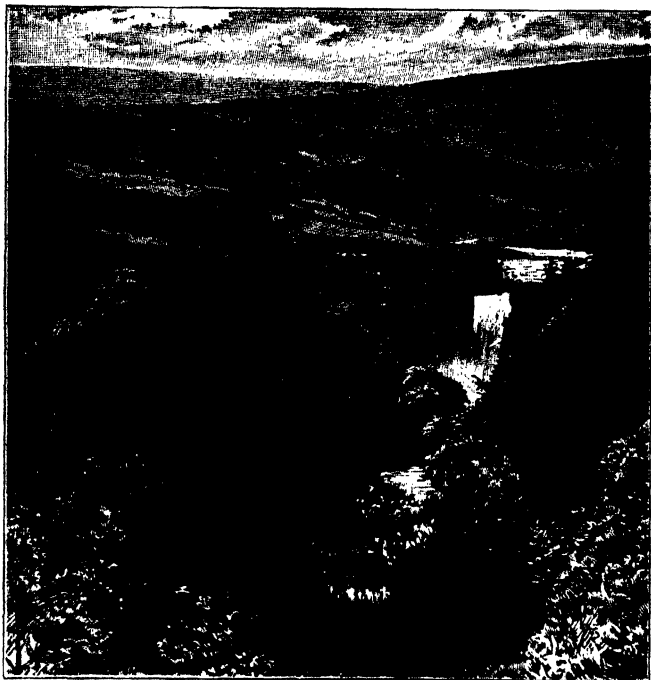


Fig. 128.—HIGH FORCE, TEENDALE.
Distant view.

all the rock were equally hard it would wear down to a spout, or sloping channel, and would make a *rapid* instead of a waterfall. As things are, the softer rock crumbles away until great pieces of the overhanging Basalt are undermined and fall, leaving a vertical cliff behind.

Above the Fall.—We climb up the steep slope by the side of the waterfall to get a wider view. Looking downstream we see the shelf of Basalt running along the sides of the gorge, and getting higher and higher above the stream, until it bends round the hill-side, and is lost to

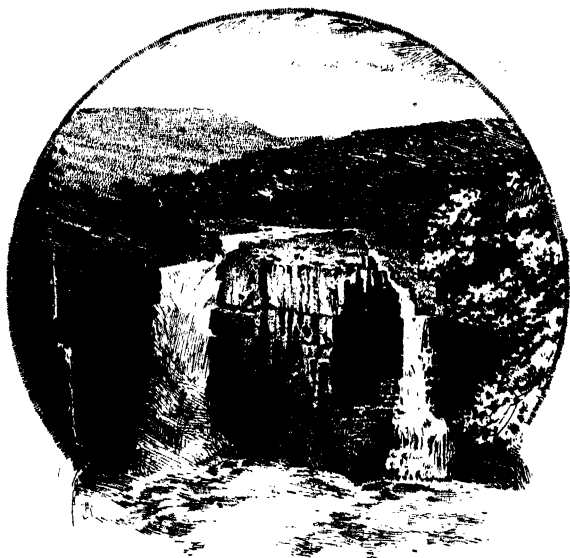


Fig. 129.—HIGH FORCE, TEESDALE.

sight. Once that Basalt stretched across in an unbroken sheet, but the river has filed away at it for long ages, and has at length filed this deep notch. The work is still going on, and in time Basalt which is now deep in the hill-side will be brought to light, and cut through. Part will be ground to powder, and part will be left as a winding ledge overhanging the river.

Let us turn and look towards the top of the fall. A wide country opens out before us, wild and bare for the most part, with plantations of firs, and heathery mountains, and a white road rising gradually to the sky-line. The river is soon lost to view among copses of alder. Look at these big stones! Some of them are like haycocks. How did they come here? Well, you can see that they have got their corners broken and worn away. I fancy that they are now and then rolled along for a few yards at a time in winter floods. There are few small stones here. Everything that can easily be moved is swept down when the river is swollen by rain.

We have still many miles to go before we reach the springs of the river. Many waterfalls and many rapids have to be passed. Between one fall or rapid and the next is generally a *strath*, or stretch of flat ground spread with shingle and sand, in which the river forms loops and bends.

Rate of rise and Rate of flow.—The bed of the river gets steeper and steeper as we ascend. In the thirty miles next to the sea, the total fall was only 380 feet, about 13 feet to the mile. For the next ten miles it was 60 feet in the mile. In the ten miles above that it rose to 75 feet in the mile. After that the slope grows rapidly steeper, until we come to a rise of 1,200 feet in the last mile below the summit ridge. You would think that the river must rush very rapidly where the fall is great. It does flow very fast in places, but it is soon checked again, and on the whole it does not come down any faster than where it has a more level course. There is much time lost at waterfalls, where all the speed previously gained is destroyed, and the current has to begin again. Besides, a small stream meets with more resistance from the ground

than a large one. A river only a yard deep rubs hard against the ground, and is prevented by that means from moving very fast. Double its depth, and the rate of flow at the surface is increased, for the upper layers of water then glide over *water*, instead of over a rough and rocky bed. I know of a mountain stream whose rate of flow was timed by damming up the water for some hours, and then letting it go in one flood. Observers were stationed to note the time in which the water rose. It took an hour and a half to flow a distance of under three miles, the fall being 600 feet. The rate of flow was therefore only about two miles an hour. A river flowing steadily in a nearly flat valley has been known to show a rate of four or five miles an hour towards the middle of its surface, but of course a great deal of the water in the river would flow much slower than that. The swiftest rivers are of large size, and flow along a gently sloping channel, without rapids or waterfalls. The swiftest river I have ever seen is the Rhine between Strasburg and Mayence. There it is deep enough for large steamers.

Scree.—I want you to look for a moment at this hill-side, covered with loose stones. The stones are not rounded like those in the bed of the river, but rough, with sharp edges and corners. Where did they come from? No doubt from that low cliff at the top of the slope, which is made of the very same rock. What has broken them small, and brought them down? The frost. Cracks run through the rock, and in the winter it often happens that water makes its way into the cracks, and freezes there. The water swells a little in the act of freezing, and wedges bits of the rock out of their place. They do not fall at once, because they are frozen fast; but when a thaw comes, a number

of pieces, great and small, are quite loose, and ready to tumble. This goes on, winter after winter, and at last there is a great bank of loose stones. We call them *Screes* in the North Country. Sooner or later the loose stones get into a water-course, and are turned over, and rolled along, whenever the stream is in flood. Thus they make their way into the main river, and if they are not first ground to sand and mud, they roll over the big waterfall, and creep little by little down the valley. There are thousands of round pebbles buried in banks of drift* miles lower down, which once formed part of the very hill on which we are standing. The stones were wedged out by frost, and sent rattling down the screes. Then they slid and rolled along the bed of the stream, getting rounder and rounder as they travelled. Now they are resting for a time, it may be for tens of thousands of years. But it is only for a time. Some day the river will wash them out again, and carry them a stage farther. They will all get ground to powder in the end.

The last Climb.—At last we set foot on the moors. There are no trees here, and no turf. All is heather, and coarse grasses, and peat, and white stones. Curlews and plovers scream around. The stream is so narrow that we can wade across anywhere. We have now risen above the sheet of Basalt, and are walking upon beds of limestone and shale. Runnels of water come trickling down from the swamps and wet slopes, and these are the springs of the river. No one can tell exactly where it begins. We have tracked it up and up, till it has parted into many threads of running water. Now let us push on to that

* *Drift* means gravel or sand *driven* along the bed of a river. We speak of a bank of snow piled up by the wind as a *snowdrift*.

hill-top straight in front. We climb to the edge, and see on the further side new slopes with new brooks soaking through them, and running together to make other rivers. Here is the *water-parting*, or water-shed, the very summit of the ridge. On one side all the water flows westward towards the Irish Sea; on the other it is bound for the North Sea, though much of it will never get to the sea at all, but will be drunk up by the thirsty air on the way.

What a glorious view! We see at our feet a wide plain, with low hills rising out of it, and clumps of trees, and here and there a white house. That thin haze is the smoke of a little market-town. I see the turns of a winding stream, with the light of the afternoon sun reflected from its shining surface. There is the trail of white steam from a railway-engine speeding south. It seems to move slowly along, but we must remember that a long bit of road shrinks almost to nothing at this distance. Far away are the blue hills, peak beyond peak, and on the other side of the hills is the sea.

LESSON XXV.

HOW PLANTS FEED AND GRQW.

WANTED :—*Duckweed floating on water. An epiphytal Orchid attached to a piece of hanging cork. Many nurserymen could sell or lend such a plant. A bottle filled with water and containing a small lump of ice. A plant, such as a Thistle, charred in a shovel over a hot fire. The blackened remains, consisting mainly of Carbon, may be kept in a wide-mouthed bottle, and labelled. Water-plants in a glass bowl, exposed to bright sunlight during the Lesson.*

What do Plants live on ?—I want to tell you something about the growth of plants, but let us first find out what you know already. Can anyone tell me what plants live upon ?

Someone answers, Earth. Another says, Earth and Water. Well, these are not bad answers. You have noticed that most plants are rooted in the earth, and that if the stem or all the roots are cut through, so that the plant can draw nothing from the earth, it soon dies. Again, those children who tell me that a plant lives upon earth and water have probably noticed that it soon withers in perfectly dry earth, but revives if the earth is watered. Let me now ask you if earth is quite necessary for the growth of plants. Have you ever seen a plant growing and thriving without any earth at all about its roots ?

One child mentions a Hyacinth-bulb grown in a glass jar full of water. Another perhaps mentions Duckweed floating on the top of a pond. A third has seen an Orchid

in a green-house, fastened to a hanging piece of cork, with its roots spreading into the air, and with no earth at all about them. A fourth child mentions Ferns and weeds, which he has seen growing out of the crevices of a wall high above the ground. But here we cannot be quite sure that there was no earth about the roots. There would probably be some crumbled mortar, or dust blown by the wind, in the crevices.

Plants must have Water.—

The examples mentioned show that while most plants require moist earth about their roots, some can do without earth if they have plenty of water. One has been named which seems to thrive without either earth or water. Which was this? You will recollect in a moment. It was the Orchid in the green-house. But perhaps, after all, the Orchid may have had water brought to it. You know that water may be present when it is quite invisible. What do we know about invisible water—water which cannot be seen? Why, of course, this is *water-vapour*, or steam. There is plenty in the air of this room. How can we prove that it is there? I bring into the room a very cold object, such as a bottle filled with ice-cold water, and the invisible water in the air settles at once

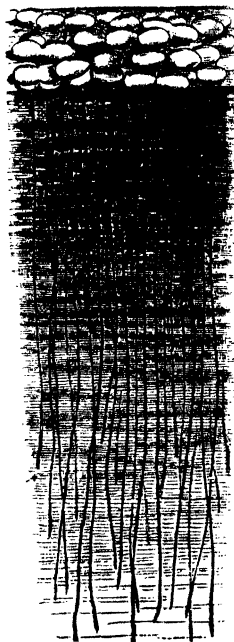


Fig. 130.—DUCKWEED.

upon the bottle in the form of fine drops. The invisible water becomes visible. The water-vapour or steam becomes



Fig. 131.—AN EPIPHYTAL ORCHID (*Acineta Humboldtii*).

liquid. Sometimes we say that the steam is *condensed*. Where did the invisible water-vapour which fills the room come from? From the drying-up or *evaporation* of *liquid* water—that is, water which can be seen, or poured from

one vessel into another. All damp things contain liquid water ready to dry up. A wet sponge may give out enough water-vapour to fill a room. Much of the water-vapour in this room comes from our own bodies. If the room is full of people, the air will contain a great deal of water-vapour, and in cold weather it will become condensed on the window-pane in the form of drops. Why on the window-pane? Because it is coldest there.

The Orchid that we have been talking about has really had as much water supplied to it as it requires, but the water was not visible or liquid; it was water-vapour, or steam.

Plants require Carbon also.—We have got as far as this, that plants require water, and that most plants require earth as well. Is that all that they want, or do they obtain food from anything else? We can throw some light upon this question by *charring* a plant. Take any fresh-gathered plant of convenient size, shake off all the earth from the roots, dry the plant in the oven for a few minutes, and then put it into a large shovel, and hold it over a hot fire. Take care that the shovel does not become too hot, or the blackened remains will begin to glow, and in a few minutes will waste away, leaving nothing but white ash. If we char the plant carefully, we shall have nothing but a black and shrivelled object left in the shovel. The water contained in the living plant has gone off as steam, and some other things which helped to make up the living plant have gone off as smoke. What remains consists almost entirely of charcoal or Carbon. Now you see why we did not allow the plant to get red-hot. Had we done so, the charcoal or Carbon would have united with the Oxygen of the air, and burnt away.

What would have been formed by the Carbon and Oxygen when united by burning? Carbon Dioxide.

So long as a plant lives, it goes on adding to its store of Carbon. A young seedling contains very little Carbon, not enough to fill a thimble. A full-grown tree contains very much Carbon, enough to fill a cart. Where does the Carbon come from?

Plants get Carbon from the Air.—Air, we know, contains some Carbon. It is true that there are no specks of unmixed black Carbon to be seen in the air, except in smoky towns. The Carbon in the air is all *combined*. With what? With Oxygen. What do the Carbon and Oxygen form when combined? Carbon Dioxide. How can we prove that Carbon Dioxide exists in the air? Well, we have proved that once before. You remember that we left some Lime-water exposed to the air, and that the Lime-water, which was at first quite clear, slowly turned milky, because of the formation of Chalk — Carbon Dioxide combined with Lime. All the Carbon Dioxide came from the air around. We know then that there is Carbon Dioxide in the air, from which plants might possibly obtain a supply of Carbon. Can living plants break up Carbon Dioxide, and obtain from it the Carbon which they require? Yes, they can. We can almost see them at work when we feed the leaves of a living plant with Carbon Dioxide, and watch what goes on with the help of a microscope. But it is quite impossible to show a number of persons at once what takes place inside a living leaf, and even if you were to see for yourselves, you would understand very little about it as yet. I must be satisfied for to-day with convincing you that the living plant stores up Carbon, that it does so when the

water and earth contain no Carbon at all, and that it gets all its Carbon from the Carbon Dioxide of the air.

Green Plants break up Carbon Dioxide, and set the Oxygen free.—Carbon Dioxide consists of two things—Carbon and Oxygen. We have seen what the living green plant does with the Carbon; it stores it up for food. What becomes of the Oxygen? If the sun favours us by shining brightly I can show you.

Here is a glass bowl containing a number of green water-weeds, which have been standing for some hours in the sun. If you watch them closely, you will see now and then a tiny bubble rising from the weeds to the top of the water. Sometimes a regular train of bubbles will be seen to rise from the same leaf one after another. We can collect these bubbles in a glass tube. Do not forget that the tube must be completely filled with water at starting, and that its open mouth must be turned down, and kept below the surface of the water in the bowl. If we do not take some pains, air will rush in and fill the tube.* A good deal of time is wanted to collect enough

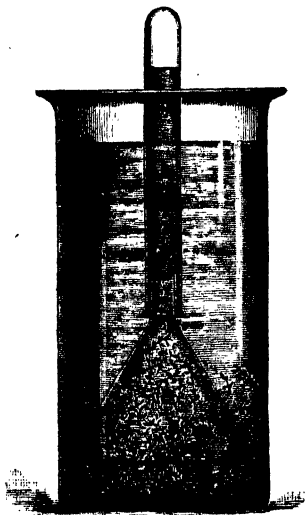


Fig. 132.—COLLECTION OF OXYGEN FROM WATER-WEEDS. (*After Detmer.*)

* It is convenient to cover a number of plants with a glass funnel turned upside-down, and to invert the collecting-tube over the pipe of the funnel.

bubbles to examine properly. If the experiment is made carefully, it is possible to prove that the gas collected in this way is Oxygen, but I cannot attempt to prove it to-day.

Recapitulation.—Before we go any further, let us consider what we have learnt so far. What do plants require as food? All require water and Carbon Dioxide. Most plants thrive best when planted in the earth, but some can live in water or in air. Give examples of each kind. Mention a plant which can thrive on air, and the water-vapour and Carbon Dioxide always found in air (page 285).

Why is Carbon Dioxide necessary to plants? Because they get from Carbon Dioxide the Carbon of which a great part of their substance consists. How can we prove that a plant contains much Carbon? By charring it. What happens if a plant is kept without any Carbon Dioxide? It is starved and dies. What becomes of the Oxygen contained in the Carbon Dioxide taken into the plant? It is separated from the Carbon, and set free. Under water, bubbles appear upon green leaves when exposed to sunlight.

Something else required.—I have told you that all plants require as food water and Carbon Dioxide, but you must be careful not to suppose that they require nothing else. Out of water and Carbon Dioxide a plant can form what we may call its skeleton, but something else is wanted for the growth of its living substance. I will explain what is meant by *skeleton* and *living substance*.

The Skeleton of a Plant.—The skeleton of a plant is not very like that of an animal. It does not consist of bone, but of paper,* or of wood and paper. No muscles

* Not manufactured paper, of course, but the same substance in its natural form.

are attached to it. It consists of a vast multitude of cells, or compartments, which contain what I have called the living substance. If you dry a leaf or a whole plant, the living substance shrinks almost to nothing, but the skeleton is not much altered. If you heat the dried plant strongly, the skeleton turns black, as paper would do. It contains much Carbon, just as paper does.

Is it strictly true that the skeleton of a plant consists of paper? Well, let us consider what paper is. It is made from linen rags, or sometimes from wood and straw. These things are torn to pieces in water, bleached or made white, and mixed into a pulp, which is spread out very thin on wire frames and dried. Where does linen come from? It is woven from the fibres of the Flax plant. Wood consists of the fibres of trees, and straw consists of the fibres of Wheat plants. So you see that paper is made from the skeletons of plants and nothing else.

The living Substance of a Plant.—The living substance consists mainly of water, and when the plant is dried, it perishes, and shrinks up almost to nothing. You might think that it was of less importance than the skeleton, for the skeleton by itself keeps the shape of the plant very fairly, while the living substance, if squeezed out from the skeleton, would be merely a kind of watery juice. But it is the living substance which feeds, and grows, and stores up Carbon, and makes the skeleton.

Paper can be made by Plants from Air and Water.—I think it is true that a living plant might make the paper of which its skeleton consists from air and water; at least, air (including a little Carbon Dioxide) and water contain between them Carbon, Hydrogen, and Oxygen, and paper contains nothing more. But the plant wants

something more to support its own living substance, and it could not continue to make paper very long if it were starving.

The living Substance requires combined Nitrogen and other things.—The living substance, too, contains Carbon, Hydrogen, and Oxygen, but it contains something more. It contains things which plants, or at least most plants, cannot get from air and water. Nitrogen is one of these. You may perhaps be surprised to hear that plants cannot get all the Nitrogen they want from the air. Four-fifths of the air we breathe is Nitrogen; surely that is enough! Yet if we raise a seedling in a Hyacinth-glass, and give it as much air, and water, and Carbon Dioxide as it requires, it is miserably starved, and the stock of Nitrogen which it had to begin with is not increased. The plant must have *combined* Nitrogen; the pure gas is of no use to it. Saltpetre is a compound containing Nitrogen, and that will do very well. If you add a few grains of saltpetre to the water, the plant begins to mend. Pour away the pure water, and add some water which has soaked through rich garden mould, and the plant will do better still, especially if you give it saltpetre from time to time. I have kept seedlings in glasses of water till they flowered, merely by dissolving in the water small quantities of saltpetre, and salt, and compounds of lime, and iron, and other things always found in the soil.*

These necessary parts of the Food of the Plant are taken up by the Roots.—The plant growing in a Hyacinth-glass can take up these things from the water by its roots.

* Here someone may ask whether Hyacinths do not bloom when supplied with pure water only. The questioner should be reminded that a Hyacinth-bulb contains a large store of food of all kinds, saved up when it grew in the ground.

The plants in the garden or the field take them up in much the same way. Roots drink up the water of the soil, and this water contains small quantities of pretty nearly everything which a plant wants. The water flows from the roots into the stem and leaves, and supplies every part of the plant with necessary food.

The Leaves evaporate much of the Water.—The leaves breathe out a good deal of water, especially when the sun shines bright, and thus a constant upward flow is kept up. Water rises from the roots to the leaves, and passes out from the leaves into the air. But the useful things dissolved in the water do not pass out, but are saved by the plant. Do you remember that when water containing salt is distilled, the salt remains behind? (See Lesson XX.)

Some Exceptions.—There are certain plants, like an Orchid growing on cork, which can hardly get their combined Nitrogen, or Lime, or Iron through their roots. If they do, they must be satisfied with a very small quantity indeed. I am not sure that we understand how these plants manage. They certainly *appear* to get all they want from the air, and the Carbon Dioxide and water-vapour of the air. But a little combined Nitrogen and other things may reach them in ways that we do not know of. There are other plants which have no roots at all. How do they get on? Roots are almost as necessary to a plant as a mouth to an animal. Well, there are animals which have no mouths, so perhaps we need not be very much surprised to hear of plants which have no roots. There are very many ways in which both animals and plants get a living, and we do not fully understand all of them.

LESSON XXVI.

WHY LEAVES ARE GREEN.

WANTED:—*Some green leaves. Methylated Alcohol (six or eight ounces). A spoonful of Starch. A spoonful of flour. A piece of bread. A raw potato. Two Primrose-plants in pots, one exposed to sunlight, the other kept in the dark for twenty-four hours. Tincture of Iodine (one ounce), diluted with water till it has the colour of sherry. Two wide-mouthed bottles containing Primrose-leaves subjected to sunlight under the conditions explained on page 298. A beaker of green scum from a stagnant pond. Filter-paper and funnel. Some cups, saucers, and glass beakers. Bright summer sunshine is required.*

The green Colour of Leaves.—Everyone knows that leaves are green. Very nearly all leaves are green, but there are a few exceptions. Can anyone mention one? [Copper Beech, Beet, etc., may perhaps be named. Golden Feverfew and other garden varieties are of a very yellow green. It may be pointed out that all the leaves named contain plenty of green colouring-matter, disguised by red or yellow. Trees in autumn are often yellow or red. Here the green colouring-matter is changed into a different substance.] Let us find out what we can about this green colour.

Not soluble in Water.—If you put a green leaf into a saucer of water no colour comes out. It is hardly worth while to try the experiment over again, because we have often seen green leaves floating in a pond or puddle, and we know that the water is not tinged by the leaves; but

we will filter some of the green scum from a pond. You will see that the water runs off clear and colourless. If you like to soak a leaf in water for an hour, you will see that both the leaf and the water remain unchanged. Even if you mince the leaf first, cutting it up into small pieces with scissors, the green colour will hardly come out into the water at all, but some small green particles will come out, and give it a very doubtful greenish tint. Boiling in water brings out more of these green particles, but the green colouring-matter remains in the leaves with hardly any change. We say therefore that the green colouring-matter is *not soluble in water*.

Soluble in Alcohol.—Now chop up some leaves, and put them in a saucerful of Alcohol. [What is sold at the druggist's as Methylated Spirit will do very well.] The Alcohol is soon tinged green, and after a time all the colour is washed out of the leaves. The colouring-matter therefore is *soluble in Alcohol*.

We might have guessed that the colouring-matter would not be soluble in cold water, for we know that leaves are often drenched with heavy rain without any change of colour; but we could not have told, without trying, that it would turn out to be soluble in Alcohol.

How to bleach green Leaves.—If we want to remove the colour from a leaf as quickly as possible, we boil it in water for two or three minutes, and then soak it in Alcohol. In about a quarter of an hour it is almost colourless, but the Alcohol is now turned to a beautiful green. It is necessary to show you how to take the green colour out of leaves, in order that you may make a little experiment later on.

Chlorophyll.—I find it tiresome to go on talking about

the *green colouring-matter of leaves*, so I will use a single word, which has been invented to signify the same thing. This green colouring-matter is called *Chlorophyll* (pronounced *Klor-o-fill*). It is Chlorophyll which makes leaves green. Not only green leaves, but purple and yellow leaves also, generally contain plenty of green Chlorophyll, mixed with red or yellow colouring-matter.

Let us now try to make out what is the use of the Chlorophyll. We should never find it by guessing, and it took more than a hundred years to find it out by experiments.

I must first talk to you a little about *Starch*.

Starch.—Starch is used to stiffen linen, but perhaps you do not know that it is very plentiful in flour and bread and potatoes. It is chiefly because bread and potatoes contain so much Starch that we eat them, but they contain other things besides Starch which are useful as food. The Starch used in the laundry has been purified, by leaving out all these other things. It is not difficult to tell Starch from other white substances which look like it at first sight. A solution of Iodine is a ready way of proving whether Starch is present or not. The solution should be rather weak, about the colour of beer or sherry. Add a little of the solution to some Starch-paste. A blue colour is immediately seen. Add a little more to some flour-paste. The blue colour is again seen. Pour a little of the solution on a piece of bread, and then on a slice of raw potato. In each case the bluish colour is immediately produced. We find, then, that *a blue colour with Iodine solution is a test for Starch*.

Starch formed in green Leaves.—Now Starch is regularly formed in green leaves, and all the Starch in the

world has been formed there. It may be stored up in grains, as in Wheat; in roots, as in Arrowroot; in stems, as in the Sago Palm; but it was first of all formed in green leaves. This is the chief reason why plants have leaves, and why their leaves are green. *Green leaves are principally useful for forming Starch.*

Starch useful as Food.—Starch is important to us as a food. It supplies our bodies with things which are daily used up, and which are necessary to keep them in health and activity. This Starch, which we separate from potatoes or wheat by grinding and washing, was originally intended as food for the plant. *Plants, like ourselves, use Starch as food.*

By the help of a microscope we can actually see the tiny grains of Starch forming in a green leaf, but I cannot show you this to-day. The little Starch-grains grow very fast, and are soon used up. All the new parts, such as new leaves or new flowers, are formed to a great extent, but not altogether, out of Starch.

Starch formed in Sunlight.—I have told you that Starch is formed nowhere except in green leaves. The next thing to notice is that it can *only be formed in sunlight*. Let us try an experiment which will make this clear.

Take two small plants of the same kind—two Primrose-plants in pots will do very well. We must lock up one in a cupboard the night before we mean to make our experiment, and keep it in the dark till the time comes. The other must be put in the garden so as to get all the sun it can. Bright weather is necessary for a good result.

When one of our Primrose-plants has stood in the sun for several hours, while the other has been left in the dark

all the time, we can find out how much Starch each has formed. Cut off a leaf from each. Mark the one that has been kept in the dark. This can be done in a moment by snipping off the tip. Now remove all the Chlorophyll from both leaves. You know how this is done. First we boil the leaves in water, and then soak them in a saucerful of Alcohol. Both leaves are soon turned to a pale yellow colour, without any green colour about them. Take them out of the Alcohol, and put them into another saucerful of weak Iodine solution. In two or three minutes one of the leaves will turn purple or bluish, while the other remains yellow as before. Now the purple or bluish tint is a mark of the presence of Starch, and you will see that it is the leaf not snipped at the tip which has turned purple. That is to say, *the green leaf which has been exposed to the sun contains plenty of Starch, but the green leaf which has been kept in the dark contains none.*

Starch cannot be formed without Carbon Dioxide.—

Now let us make a fresh experiment. I have here two wide-mouthed glass bottles. Each contains a Primrose-leaf. Both the bottles are filled with what looks like common air, but there is a difference between them. One bottle contains a little more Carbon Dioxide than common air, while the other has had all the Carbon Dioxide carefully removed from it. You know by this time how to make Carbon Dioxide. Some acid, such as dilute Hydrochloric Acid, is poured upon Chalk in a flask, so as to set Carbon Dioxide free. The gas is allowed to stream for a moment into one of the two wide-mouthed bottles, which is then carefully closed. The stopper should be well greased beforehand, in order to prevent the escape of the gas. The other bottle has had a few drops of Potash solution poured into it, to

absorb or drink up all the Carbon Dioxide. Both bottles, with the leaves in them, have since stood in the sun for several hours. We shall examine the leaves as before. They are marked, boiled in water, soaked in Alcohol, and finally soaked in a weak solution of Iodine. You now see the result. The leaf which has had plenty of Carbon Dioxide supplied to it is full of Starch, while the leaf which has been kept away from Carbon Dioxide contains no Starch. Here is a fresh fact for us. We now see that *green leaves in sunlight can form Starch if Carbon Dioxide is supplied to them, but not otherwise.*

Before we go further, let us see what we have learnt about the formation of Starch in leaves. We have found:—

1. That there is a green colouring-matter, called Chlorophyll, in all green leaves.

2. That Chlorophyll is soluble in Alcohol, but not in water.

3. That Starch can be detected by the blue colour formed when an Iodine solution is poured upon it.

4. That Starch is used for food, both by plants and by ourselves.

5. That Starch is formed only in leaves coloured green by Chlorophyll.

6. That it is formed only in green leaves exposed to sunlight.

7. That it is formed only when the leaves are supplied with Carbon Dioxide.

How Starch is formed.—You will now understand something of the way in which Starch is formed. The leaves take in Carbon Dioxide; they separate the Carbon, and use it in forming Starch; they have no use for the

Oxygen, and allow it to escape. It is quite easy to show that Starch contains a great deal of Carbon. Take some Starch-powder, and put it in a clean dry test-tube. Heat it strongly in the flame of a spirit-lamp. A dew of small drops of water will condense upon the cool sides of the upper part of the test-tube. Then the Starch will turn brown, and gradually become quite black. The black substance which is left behind, when all the water and gases are driven off by heat, is Carbon. It would not be very wide of the mark to say that leaves join together Carbon and water to form Starch, but this is not exactly what happens. To tell the truth, the wisest of us do not know all about the formation of Starch in plants, and we should be quite unable to make it for ourselves.

Starch insoluble in cold Water.—There is another thing about Starch which I have yet to explain to you. *Starch is not soluble in cold water.* Try it for yourselves, but first consider how you ought to go to work. If you think for a moment you will see the right way. Let us first make a little Starch-paste with cold water, so as to get the Starch thoroughly wetted with water. Then stir it up in a cupful of water, and let it stand. The Starch will settle slowly to the bottom. Is any left in the water? Perhaps a little, for the water is not quite clear. Let us filter the water through a piece of filter-paper stuck in a funnel. Now the water is quite clear. Does it still contain any Starch dissolved in it? We can test this. How? By our Iodine solution, of course. Pour a little of the solution into the clear water which has run from the filter. Is any blue tint produced? No. Then the water contained no Starch. You now see how to prove that Starch is insoluble in water.

How Starch travels up and down in a Plant.—But here comes in a difficulty. If Starch is insoluble in water, how does it travel up and down in the plant, so as to reach all the parts which need food? If it could have been dissolved in the watery sap, we could have understood how it might be carried about, but solid particles cannot well be carried for any distance through leaves or stems. When you know more about the way in which plants are built up, you will see plainly that no solid particles can travel even for a quarter of an inch through a leaf. We seem to have got into a hopeless difficulty. But our difficulty simply proceeds from the fact that we have not learnt quite enough about Starch. Starch is very easily changed into a substance like Sugar, which dissolves in water, and it is also easily changed back again into common Starch. When the sun shines upon the leaves, the dissolved Starch soon becomes solid again, and quite insoluble in water, but in the dark it is very ready to change into the other form, which is perfectly soluble in water. Starch is therefore *formed only by day*, but it *passes out of the leaves chiefly by night*. All the Starch which we found in our Primrose-leaves was not fresh-formed from Carbon Dioxide. Some of it had no doubt been circulating in the dissolved state for some time.

A green Plant deprived of Leaves would starve.—What would be the effect of removing all the leaves from a plant, and cutting off the new ones as they came out? Why, the plant would not be able to separate Carbon from the Carbon Dioxide of the air; it could form no Starch; and the roots and stem would soon suffer for want of food. If you kept on removing the leaves for a long time, the plant would die of starvation.

Now let us gather up the substance of our lesson into a few words.

1. Green plants form Starch in sunlight.
2. They must be supplied with Carbon Dioxide in order to do so.
3. Oxygen is set free at the same time.
4. Starch is food for the plant, and we take it away from the plant in order that it may be food for ourselves.
5. Green leaves are chiefly useful to the plant as a means of forming Starch.



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